Tokenized Disaggregated Credit & Decentralized Institutional Monetary Design

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Abstract

This working paper presents a high-level overview regarding a proposed monetary institutional design and incentive structure that utilizes blockchain technology. The aim of this paper is to illustrate how the fungibility-agnostic tokenization of credit allocation and the *Quantity Theorem of Disaggregated Credit* can be combined to create a dynamic decentralized monetary institutional design on the blockchain. The result is an institutional design proposal and policy toolkit that is both simple and deployable at scale. The goal of the following proposed institutional design is to achieve financial stability, robust economic growth, generate more efficient job growth, and reduce the negative externalities caused by societal inequality.

Keywords: blockchain, monetary policy, credit creation, tokenization, ERC1155, RPG, video games, institutional design, game development, banking

Tokenized Disaggregated Credit & Decentralized Institutional Monetary Design

Before applying blockchain to any institutional design, it is imperative to first acquire sufficient domain knowledge of the fundamental functions within the current institution itself. A first principles approach within any given domain is tantamount as a base case for institutional analysis, design conceptualization, product development, prototype testing, and implementation. The first principles approach in this paper pertains to a frequently overlooked phenomena in mainstream economic literature: money creation and the role of banks. Both the interpretation and real-world function of these two variables are at the heart of this paper's monetary institutional design conceptualization. This paper focuses on the *Credit Creation Theory of Banking* (Werner, 2014), and by extension, the *Quantity Theorem of Disaggregated Credit* (Werner, 2005), as first principles for design consideration. Specifically, the fungibility-agnostic tokenization characteristic of these theories is incorporated with the ERC1155 token standard. Lastly, incentive structures are addressed such that the composition of the proposed monetary institutional design encourages transparent cooperative behavior between all economic agents.

Before applying blockchain to economic institutional design, we need to take a step back and identify the core first principles of macroeconomic domain knowledge: the role of money creation and banking.

Old School Is New School

Money Is Credit Creation

What is money and how is it created? The answer to this question is the first step in decentralized institutional monetary design and how we can layer the blockchain on top of it. In addition, the precise answer to this question is the most important foundational pillar in all of economics. Should we fail to answer this question accurately, we run the risk of designing a monetary institutional structure that may unintentionally impose adverse selection and moral hazard upon society, resulting in economic growth that is not robust while lacking in antifragility. In general, when analyzing and designing economic systems, Bastiat (1850) provides a helpful ecologically rational heuristic:

> In the department of economy, an act, a habit, an institution, a law, gives birth not only to an effect, but to a series of effects. Of these effects, the first only is immediate; it manifests itself simultaneously with its cause – it is seen. The others unfold in succession – they are not seen: it is well for us, if they are foreseen. Between a good and bad economist this constitutes the whole difference – the one takes account of the visible effect; the other takes account both of the effects which are seen, and also of those which it is necessary to foresee. Now this difference is enormous, for it almost always happens that when the immediate consequence is favorable, the ultimate consequences are fatal, and the converse. Hence it follows that the bad economist pursues a small present good, which will be followed by a great evil to come, while the true economist pursues a great good to come – at the risk of a small present evil. (p. 41)

Surprisingly, there is no unilateral consensus among economists as to what money is or how it is created. Werner's (2014) evaluation of the economic literature illustrates this insight with empirical studies of money creation proposing three general theories among economists regarding the role of banking in the economy. Thus, to answer the money question, we need to first understand what role banks play in these theories. The three theories are the *financial intermediation theory,* the *fractional reserve theory,* and the *credit creation theory*. The conscious choice of which of these three theories to accept as reality is of critical importance regarding the effectiveness of decentralized monetary blockchain institutional design. This paper chooses to accept the oldest theory, the credit creation theory of banking, and by its extension, the Quantity Theorem of Disaggregated Credit as reality. Out of the three theories mentioned, the credit creation theory of banking is the only one which has been empirically tested and verified as true (Werner, 2005). This novel empirical testing is the main reason why the author of this paper cites Werner's work frequently. It is beyond the current scope of this paper to delve into a comparison of all three theories in sufficient detail since this paper's focus is on the blockchain implementation of the *credit creation theory of banking* in decentralized monetary institutional design. To better understand the author's choice of the credit creation theory of banking, it is suggested that the reader first consult Werner's paper (2014) which addresses all three theories, and empirical findings, in detail.

Endo or Exo? Credit Creation, Money, & Banking

Most economics textbooks and education assert that the role of banks are as financial intermediaries and that credit creation does, in fact, occur. However, the specificity of *how* credit is created and *allocated* appears to be far different than what happens in actual practice. Furthermore, the concept and assertions of the money multiplier is addressed. Below, we illustrate how these assertions do not logically hold. A more specific definition of money, credit, and banking is then defined in accordance with the credit creation theory; supporting the premise that money creation and credit is not an endogenous demand-driven phenomena. Rather, credit creation is oriented toward an exogenous short-side supply phenomena. Understanding these simple, but subtle, nuances regarding this intersection of monetary and banking interaction in the economy is imperative to specifying the choice of token standard, incentive structure, and overall decentralized monetary institutional design considerations.

The Money Multiplier

Ryan-Collins et al. (2012) note the following description of how most textbooks explain the mechanics of the money multiplier:

> A member of the public deposits his salary of £1000 into Bank A. The bank knows that, on average, the customer will not need the whole of his £1000 returned at the same time – it is more likely that he will spend an average of £30 a day over the course of a month. Consequently, the bank assumes that much of the money deposited is 'idle' or spare and will not be needed on any particular day. It keeps, or is mandated to keep by the central bank, back a small 'reserve' of say 10 per cent of the money deposited with it (in the case of £100), and lends out the other £900 to somebody who needs a loan.
>
> Now both the original depositor and the new borrower think they have money in their bank accounts. The original deposit of £1000 has turned into bank 'deposits' of £1900 comprising £1000 from the original deposit plus £900 lent to the borrower.
>
> This £900 is then spent in the economy, and the shop or business that receives that money deposits it back into Bank B. Bank B then keeps £90 of this as its own reserve, while lending out the remaining £810. Again the process continues, with the £810 being spent and re-deposited in Bank C, who this time keeps a reserve of £81 while re-lending £729.

> At each point in the re-lending process, the sum balance of all the public's bank accounts increases, and in effect, new money, or purchasing power, has been created.
>
> This process continues, with the amount being lent getting smaller at each stage, until after 204 cycles of this process the total balance of the public's bank deposits has grown to £10,000. (p. 18)

Mathematically, the money multiplier defines a specific function with logarithmic properties. In the recently cited example, the plateau of the money multiplier function reaches £10,000 at the limit. Knowing the shape of the money multiplier's mathematical function quickly allows us to realize that it can't logically exist nor can it be utilized as a definition of credit creation that exists in the real world. As noted by Ryan-Collins et al., a "reserve ratio of 2% the multiplier stops having an effect at around 1140 cycles and, in an economy of 61 million people, this number of cycles of re-lending would take a few weeks at most" (p. 20). In the case of larger country populations, such as the US, the cyclical effect would be even more pronounced.

A prime logical critique of the money multiplier model is that, by definition, it is a logarithmic function with a hard bounded cap, or limit. Thus, ascribing to the money multiplier economic model makes the assumption that the money supply is always contained. From a deductive logic standpoint, this makes sense, but when inductively considering how the money supply works in the real world, the deductive approach fails to support the money multiplier model. Specifically, it is well known in practice that banks aren't restricted by some sort of deposit quota in order to make loans. In other words, banks will lend to an entity if they *believe* that entity can repay the loan.

When banks lend money, they purchase the loan contract from the borrower, which the bank puts on its balance sheet as an asset. The bank then owes the loaned money amount to borrower, which the bank puts on its balance sheet as a liability. Thus, assets equal liabilities on the balance sheet wherein the bank has literally created money out of nothing (Werner, 2014). No other entity on Earth can perform money creation other than banks, which allows banks to have a very unique role in society. As noted over a century ago by the economist Innes (1913), whose work John Maynard Keynes praised:

> Credit is the purchasing power so often mentioned in economic works as being one of the principal attributes of money, and as I shall try to show, credit and credit alone is money. Credit and not gold or silver is the one property which all men seek, and acquisition of which is the aim and object of all commerce.

Several years after the Bretton Woods system was terminated in 1971, it is noted by Friedman (1979):

> Until fairly recently, the power of the Federal Reserve Banks to create currency and deposits was limited by the amount of gold held by the System. That limit has now been removed so that today there is no effective limit except the discretion of the people in charge of the System. (p. 67)

Thus, all banks ration credit via lending which creates new money in the economy (Werner, 2005, pp. 193, 194). In the case of credit (money) creation originating in United States banks, the money is defined as a fungible *currency* called "dollars". This is how the money supply is created. It is not bounded by a plateauing mathematical function nor is it demand driven. Rather, credit creation, which is money creation, starts with banks, whose obtainment and retainment of banking licenses requires government approval. Credit creation is unbounded in nature, exogenous, and a short-side supply phenomena dictated by rationing from banks through lending. These important intrinsic real-world properties of credit creation have their own unique merits, risks, and incentive structures within all economies from the past to the present. Another subtly vital property of credit creation noted by Modern Monetary Theory is that “the currency itself is a simple public monopoly” (Mosler, 2021). All of these prior mentioned properties heavily influence a blockchain decentralized monetary institutional design, policy toolkit, and incentive structure.

What Banks Are

If banks are not financial intermediaries, but instead creators of credit within a network, and the currency is a public monopoly, how do we categorize banks when thinking about blockchain institutional design? This paper defines banks as analogous to public-private utilities with the monopoly power to create and ration credit wherein the currency is also a public monopoly. The unique role of banks in this definition implies that they have a *de facto* public-private partnership with the communities upon whom they serve and their shareholders. Thus, the overall functioning of a blockchain monetary institutional design must consider this public-private aspect.

The Disaggregated Equation of Exchange

The equation of exchange, and especially Fisher’s algebraic notation of it, is a pillar in monetary economics. However, this paper takes the viewpoint that the traditional and commonly used forms of the equation of exchange are only true under certain restricted circumstances. Given that, the equation of exchange is still very useful, but it needs to be defined differently to be practically useful in today’s economic modeling efforts and when approaching blockchain monetary institutional design. This paper utilizes Werner’s (2005) *Disaggregated Equation of Exchange* as the definition to be used, derived below at extensive length:

Let us recall that the original transaction-based equation of exchange states that *the amount of money changing hands to pay for transactions during a given time period must be equal to the nominal value of these transactions.* Following the traditional way of formulating this (though replacing Fisher's T with the slightly intuitive notation Q for the quantity of transactions) we get:

(4) $MV = PQ$

where MV now does not stand for an arbitrary measure of the money supply, but the total amount of money actually changing hands as part of transactions, while PQ stands for the value of these same transactions. Next, a disaggregation into GDP-based transactions and those not part of GDP is necessary.

Theoretically, we can of course disaggregate the transaction data in any way we wish. It will become an empirical issue whether we can find good statistical data to proxy the theoretical breakdown. As discussed, and following Werner (1992, 1997d), we choose to break both sides of (4) down: on the one hand, into money used for transactions that are part of GDP ($M_R V_R$) and those that are not (called $M_F V_F$); and on the other hand, the value of transactions that are part of GDP ($P_R Q_R = P_R Y$), and those that are not ($P_R Q_R$):

(5) $MV = M_R V_R + M_F V_F$

(6) $PQ = P_R Q_R + P_F Q_F$

At the same time, equations (6) and (7) must also hold:

(7) $M_R V_R = P_R Q_R$

(8) $M_F V_F = P_F Q_F$

Since we defined $P_R Q_R$ as the value of all GDP-based transactions, we also know that the following equation holds, where P_R stands for the GDP deflator and ($P_R Y$) stands for nominal GDP.

(7') $M_R V_R = P_R Y$

with $V_R = (P_R Y) / M_R = \text{const.}$

With a stable 'real' velocity of money, V_R, the effective amount of money used for GDP transactions during any period of time ($M_R V_R$) must be equal to nominal GDP. Meanwhile, the amount of money effectively used for non-GDP transactions will be equal to the value of those non-GDP transactions…

(9) $\Delta MV = \Delta(PQ)$

This merely restates that an increase in the value of transactions (and hence economic growth) can only take place if there has been an increase in the amount of money used to conduct these transactions. Dividing both the change in the amount of money used for transactions and the change in the value of transactions into those that are part of the GDP definition (ΔM_R and ΔQ_R) and those that are not (ΔM_F and ΔQ_F), we obtain:

(10) $\Delta MV = \Delta M_R V_R + \Delta M_F V_F$

(11) $\Delta(PQ) = \Delta(P_R Q_R) + \Delta(P_F Q_F)$

At the same time, equations (12) and (13) must also hold:

(12) $\Delta M_R V_R = \Delta(P_R Q_R) = \Delta(P_R Y)$

(13) $\Delta M_F V_F = \Delta(P_F Q_F)$

We can say that the rise (fall) in the amount of money used for GDP-based transactions is equal to the rise (fall) in nominal GDP. Similarly, the rise (fall) in the amount of money used for non-GDP transactions is equal to the change in the value of non-GDP transactions. (pp. 185, 186)

It is vital to precisely define what the variable M truly represents. Contrary to what was assumed by Fisher, Keynes, and other postwar economists, deposit aggregates pertaining to M0 and M4 are not sufficient definitions. Those M measures are subsets of private sector savings: private sector savings aggregates. We cannot use them in the equation of exchange because at the moment they are measured, they are not being used for transactions and only represent potential (not effective) purchasing power. They represent the 'savings supply' and not the 'money supply'. Instead, M should be defined as bank generated credit that is newly created, because it is the increase in money that is used for transactions. (Werner 2005, pp. 187, 188). This general view of new credit creation resulting in the definition of the money supply is not at all new in the history of economics, despite the different legal interpretations of money and credit, as Werner (2005) notes:

> This has been recognized by Pollexfen (1697), Law (1720), and Thornton (1802), among others, but failed to become the mainstream view due to the erroneous fixation on legal tender on metallic money… (p. 188)

Given this powerful insight from antiquity, it is possible to measure M with the variable ΔC defined as credit creation. As Werner (2005) specifies, continuing the previous derivation steps:

> (14) $CV = PQ$
>
> (15) $CV = C_R V_R + C_F V_F$
>
> (16) $PQ = P_R Q_R + P_F Q_F$
>
> (17) $C_R V_R = P_R Q_R$
>
> Since we defined $P_R Q_R$ as the value of all GDP-based transactions, we also know that the following equation holds, where P_R stands for the GDP deflator and ($P_R Y$) stands for nominal GDP.
>
> (17') $C_R V_R = P_R Y$
>
> with $V_R = (P_R Y)/C_R = \text{const.}$
>
> (18) $C_F V_F = P_F Q_F$
>
> with $V_F = P_F Q_F / C_F = \text{const.}$
>
> For growth:

(19) $\Delta CV = \Delta(PQ)$

(20) $\Delta CV = \Delta C_R V_R + \Delta C_F V_F$

(21) $\Delta(PQ) = \Delta(P_R Q_R) + \Delta(P_F Q_F)$

At the same time:

(22) $\Delta C_R V_R = \Delta(P_R Q_R) = \Delta P_R Y$

(23) $\Delta C_F V_F = \Delta(P_F Q_F)$ (p. 190)

This disequilibrium model of the equation of exchange, resulting in a unique credit creation model, does not have to utilize the money multiplier or equilibrium economics. In particular, Walrasian, DSGE, or IS-LM models are of little value in this model. Since bank credit is defined as being rationed, an activity exclusively provided to banks defined by quantity, market clearing will not occur due to imperfect information and price not being the deterministic variable. The result is an elegant and simple model that provides the necessary practical flexibility required to incorporate blockchain technology into decentralized monetary institutional design. Markets are rationed, not determined by prices, and map to dynamic disequilibrium economics. Market equilibrium is the very rare fleeting exception and not the common norm.

The Quantity Theorem of Disaggregated Credit

Revisiting the *Disaggregated Equation of Exchange*, above, it is now possible to restate that disequilibrium model into the *Quantity Theorem of Disaggregated Credit*, as formally conceived and stated by Werner (2005):

(14') $PQ = CV$

(17'') $P_R Q_R = C_R V_R$

with $V_R = (P_R Y)/C_R = \text{const.}$

(18’) $P_F Q_F = C_F V_F$

Thus the two key equations of our model can be restates as follows:

(22’) $\Delta(P_R Y) = V_R \Delta C_R$

(23’) $\Delta(P_F Q_F) = V_F \Delta C_F$ (p 200)

The Tokenization of Quantified Disaggregated Credit

This section proposes the application of the fungibility-agnostic tokenization of credit using the ERC1155 standard to *The Quantity Theorem of Disaggregated Credit* in order to create a dynamic decentralized monetary institutional design that fosters both economic growth and social welfare simultaneously. Issues and concerns regarding interest rates, economic growth, development, consumption, inflation, deflation, and bank collateralization are addressed.

Stimulation Funded by Bank Borrowing:

This section first addresses a framework of how disaggregated credit creation for economic growth works without blockchain and then proceeds to later that framework while layering blockchain on top of it.

The typical way that economies are stimulated is through bond issuance via institutional policy, which is financed with money. However, this causes quantity-crowding out from parts of the private sector by removing existing purchasing power from it. The negative externalities caused by economic stimulus through bond issuance can be mitigated, as Werner (2005) points out via empirical studies of Japan as an example:

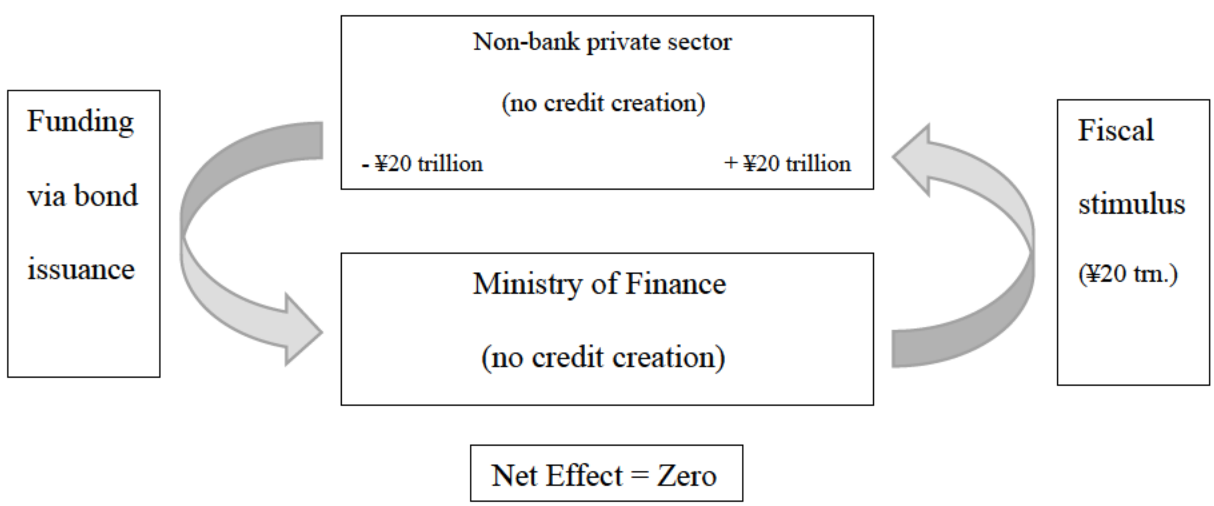
> …the institutional reality of the banking system allows banks to create new purchasing power without withdrawing existing purchasing power from other

> parts of the economy… using Japanese data, no evidence can be found that interest rates are in inverse relationship with the quantity of bank loans extended. Furthermore, Japanese banks as of early 2005 had excess reserves of over ¥30 trillion with the central bank, and continued to reduce bank lending… Unlike bond markets, banks create new purchasing power when they lend.
> (p. 255)

A visual representation of how these two methods of stimulus differ is shown below in the context of the Japanese economy (Werner 2005, p. 256):

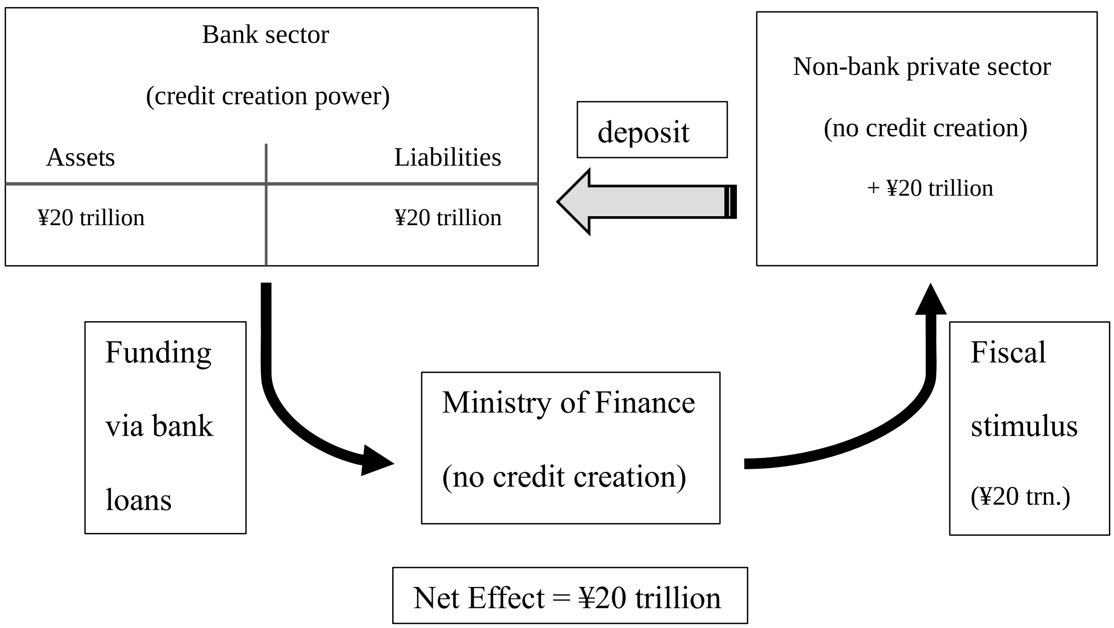
<u>Fiscal Stimulation Funded by Bond Issuance</u>

(e.g.: ¥20 trillion government spending package)



Fiscal Stimulation Funded by Bank Borrowing

(e.g.: ¥20 trillion government spending package)



It should be noted that the role of the Ministry of Finance can be replaced, or combined, with that of the Central Bank in the stimulation framework given above. In other words, when switching context to the US economy, the model allows institutional flexibility such that either the Treasury or Federal Reserve can conceivably engage in such economic stimulatory methods.

Economic growth is only possible through the rationing of new bank credit. The only budget limit imposed on such a method is credit creation. In order to grow nominal GDP, new credit needs to be created and allocated for GDP transactions and not for transactions related financial or speculative transactions (Werner, 2005, p. 207):

$$(1)\quad \Delta(P_R Y) = V_R \Delta C_R$$

Inflation and Deflation. How will this model trigger inflation or deflation? In general, it depends on the potential growth rate of the economy. When actual growth reaches the maximum potential growth rate, marginal credit creation will result in nominal GDP growth and inflation. Deflation results when GDP growth is below potential growth. Note that in this model, credit is not endogenous to nominal GDP and the generalized production function is provided below via Werner (2005, pp. 207, 208, 221):

$$(2)\quad Y^* = f(QFI^*; TFP^*)$$

where Y^* stands for potential real output, which is a function of quantity factor of inputs, (QFI) and the quality of their use (total factor productivity, TFP). Potential output can also be considered akin to the aggregate supply of the economy.

Inflation will occur due to increases in C_R; however, within our disequilibrium model of credit creation, increases in C_R is "reflected in an increase in the GDP deflator" and "real GDP, Y, will remain unchanged." (Werner, p. 209) Inflation will not occur if actual output is below potential output since a dollar in new credit creation can map to equal one dollar in new real output and income. In other words an "increase in nominal GDP (PY) will be entirely due to rises in real GDP (Y)." (Werner, p. 209). Such underutilization of factor inputs is currently what most countries globally are going through at the time of this writing when reviewing factory output, dry bulk shipping demand, unemployment, and other macroeconomic growth data.

Consumption. If new credit creation is allocated to consumption, C_C, output doesn't change. When output gets close to full employment and more C_C is created, transactions increase resulting in consumer price inflation. If new credit creation is used for financial and speculative transactions, C_F, consumer price inflation and output will not occur. Rather, nominal rises in asset price inflation will certainly occur, such as inflation regarding nominal prices of equities and housing. As C_F increases, the likelihood of market bubbles, and market bubble growth, increases. Every single market bubble, and market bubble burst, in human history can be attributed to the rate of change and allocation path of C_F as the originating source.

Economic Development. Banks can create, and allocate, new credit creation such that an increase of the potential growth rate is possible. The result is non-inflationary with increased output that can exceed the prior full employment level. The potential in this case is lifted due to the creation of new credit being incrementally allocated over time to productive uses boosting QFI and

TFP, with the result being implementation of new technologies. New technologies have increasing returns to scale and growth in human capital. Thus, a rise in the full employment level of output occurs wherein both frictional and natural unemployment can exist such that inflation is not triggered. (Werner, p. 212)

Effectiveness of Interest Rates. Empirical tests of the *Quantity Theorem of Disaggregated Credit* pertaining to nominal GDP growth of Japan from 1984 to 2001 conducted by Werner (2005) reveal that, "Lowering (or raising) interest rates does not have any significant impact on economic growth." (Werner, pp. 218-222)

Bank Collateral & Ergodicity. Bank asset collateralization influences the prices of the assets they collateralize. However, each node (a bank) in any given credit creation network behaviorally assumes it does not affect collateral asset prices. This behavior of individual banks often results in negative externalities, and specifically, unsustainable asset price inflation. Put succinctly, bank behavior in this context is non-ergodic and not ergodic. More specifically, this means the time average of asset price appreciation of an individually observed bank within a network of banks engaged in the same behavior, from newly created bank credit pertaining to C_F, does not equal its expected value. In formal parlance, Birkhoff's equation, below, is not satisfied, which is the test for ergodicity, as noted by Peters (2019):

(1) $$\lim_{T\to\infty}\frac{1}{T}\int_0^T f\big(\omega(t)\big)dt = \int_\Omega f(\omega)P(\omega)d\omega$$

Time value of *f* Expected value of *f*

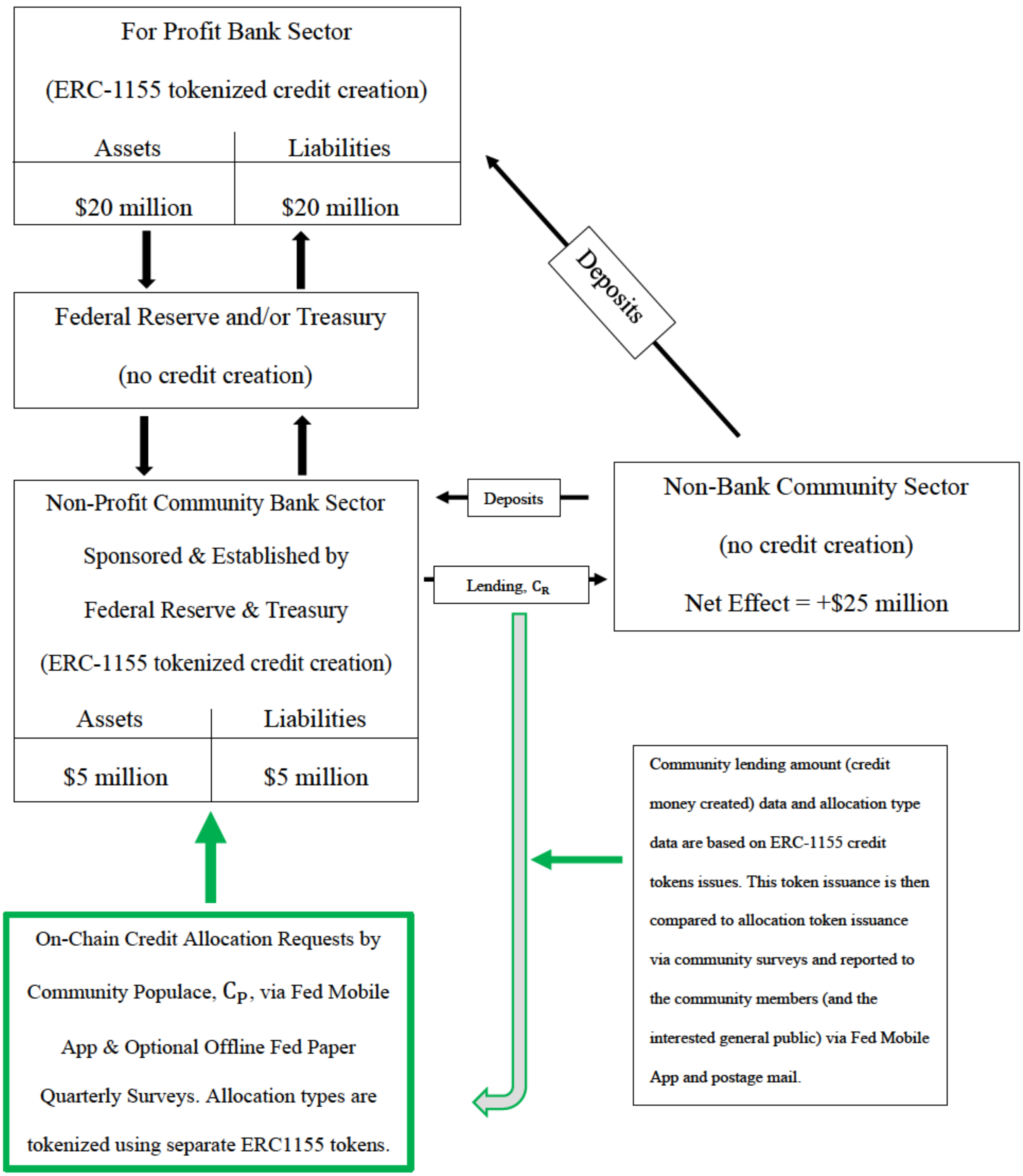
> Here, f is determined by the system's state ω. On the left-hand side, the state in turn depends on time t. On the right-hand side, a timeless $P(\omega)$ assigns weights to ω. If equation (1) holds we can avoid integrating over time (up to the divergent averaging time, T, on the left), and instead integrate over the space of all states, Ω (on the right). In our case $P(\omega)$ is given as the distribution of a stochastic process. In systems with transient behaviour, that may require defining $P(\omega)$ as the $t \to \infty$ limit of a time dependent density function $P(\omega; t)$. (p. 1216)

Since (1) is not satisfied due to bank asset collateralization being non-ergodic, this lack of equality further validates that equilibrium models and the deductive axioms of equilibrium economics cannot adequately explain, or be used, to model real world phenomena pertaining to bank credit creation. This distinction is important when considering the dynamic aspects of decentralized monetary institutional design and tokenization that is fungibility-agnostic.

Dynamic Decentralized Blockchain Stimulation Funded by Bank Borrowing

Below is a visual reinterpretation of economic stimulation and decentralized monetary institutional design using blockchain featuring the ERC1155 tokenization of new credit creation. It is envisioned as a dynamic decentralized public-private network of credit creation targeting with the focus being blockchain development for *digital credit* and not *digital currency.* This is because, transitively, the currency is inherently a public monopoly.

Dynamic Decentralized Blockchain Credit Creation Stimulation Model



The above institutional design utilizes an inductive bottom-up approach for credit creation and allocation instead of a top-down approach. The credit creation ecosystem of banks is envisioned to be diverse and cooperative composed of private and not-for-profit public community banks. It is positive reinforcing and self-reinforcing in nature, not negatively adversarial. Notice how the origin of the feedback loop within the system starts with data input from the populace's community stakeholders regarding credit allocation applied to their specific communities. This avoids many of the negative externalities, moral hazard, and inefficiencies embedded within current top-down institutional design. Bounded rationality is greatly reduced in the institutional design proposed by this paper, wherein information becomes more transparent and marginally approaches the ideal of perfect information. The transparent tokenization of credit, its value, and specific allocation when measured against the quantified credit allocation choices of the people generates a new unique metric of economic performance: $C_{R.alloc}/C_P$ where C_P represents the public's tokenized credit creation allocation type requests on the blockchain and $C_{R.alloc}$ represents the allocation types non-profit community banks allocated tokenized newly created credit to. If the ratio is not equal 1, then new credit creation (stimulus) was not completely targeted to the allocated sector types that the public community in question requested. These ratios can be placed on the blockchain as a way to assess how effective various credit allocations were over time. This would signal a potential misallocation of credit creation stimulus, which may or may not generate positive or negative externalities depending on if the credit was applied to activities that raise nominal GDP. In any event, this metric is designed to proxy economic growth, and is scale invariant. Summing up all, or any subsets, of the community ratios would produce an aggregate metric that would be a more reliable, less laggy, and dynamic proxy measure of economic growth than nominal or real

GDP. This metric allows us to know more precise economic growth performance of all element at all scales within any economic system.

Blockchain's Impact on Factor Inputs

The integration of blockchain in the disaggregated credit creation model further increases the marginal effectiveness of factor inputs. As noted by Berg et al., (2019):

> … blockchains have spillovers onto new and existing technologies, fostering deep technological interrelationships, which (as far as we know) were unforeseen by their inventor. In this argument, blockchain technology is factor augmenting. Its adoption drives economic growth by improving the productive efficiency of economic operations. This is both an intuitive and a popular understanding of the rationale for the adoption of new technology; namely that it improves efficiencies, or reduces inefficiencies, with a superior technology to achieve a particular task. People adopt the new technology because of these marginal productive efficiency gains. Technology change makes one or more input factors more productive. (p. 16)

Fungibility-Agnosticism and the ERC1155 Token Standard

There are two important points of logic regarding the Quantified Disaggregated Credit model that must be compatible with the choice of a token standard: *what* is newly created credit being allocated to and *how much*. The *what* (specific sector or economic entity, depending how much we want to disaggregate) is non-fungible while the *how much* (credit money) is fungible. Thus, the choice of token standard is crucial, and must be able to provide fungible and non-fungible functionality. By extension, a decentralized monetary institutional design must support this functionality before consideration of integrating it with blockchain. This is what makes the

Quantified Disaggregated Credit model and ERC1155 the preferred, and optimal, feature combination as a foundation for blockchain development in the context of economic stimulation via institutional design.

The advantages of ERC1155 compared to ERC20, ERC721, and ERC777 are considerable. These advantages are noted in the docs of OpenZeppelin:

> The distinctive feature of ERC1155 is that it uses a single smart contract to represent multiple tokens at once. This is why its balanceOf function differs from ERC20's and ERC777's: it has an additional idargument for the identifier of the token that you want to query the balance of.
>
> This is similar to how ERC721 does things, but in that standard a token id has no concept of balance: each token is non-fungible and exists or doesn't. The ERC721 balanceOf function refers to *how many different tokens* an account has, not how many of each. On the other hand, in ERC1155 accounts have a distinct balance for each token id, and non-fungible tokens are implemented by simply minting a single one of them.
>
> This approach leads to massive gas savings for projects that require multiple tokens. Instead of deploying a new contract for each token type, a single ERC1155 token contract can hold the entire system state, reducing deployment costs and complexity.

Furthermore, the batch operations of ERC1155 allow operation of multiple tokens in a single contract. The net result is significant gas savings on the Ethereum blockchain, and in any event, Ethereum is migrating toward a proof-of-stake protocol instead of proof-of-work. Gas cost and other development factors were a legitimate concern noted in a white paper by Boston Federal Reserve researchers (2019):

> First, at the time Ethereum offered limited ability to query by a range. For example, if we sought results from transactions between $200 and $400, a query would return all transactions. Picking a subset of those transactions required a supplemental database external to the Ethereum back end.

and

> Third, ensuring consensus among participating nodes still required a proof-of-work protocol. Even within a confined environment, the time necessary to create a block was slower than could be tolerated in a production environment. Viability in this case could not be demonstrated. (pp. 10, 11)

ERC1155 provides a way to reapproach these troubleshooting issues and blockchain development obstacles related to decentralized monetary and fiscal (or a combination of the two) policy. It should also be noted that ERC1155 was created by the gaming company, Enjin, which leads us to our next section.

Gamers Know & Understand Real-World Disequilibrium Economics

Anyone who has ever played an RPG video game is already very intuitively familiar with the tokenization, allocation, and immediate impact, of things that have both fungible and non-fungible attributes. An RPG game consists of characters that the player controls in an imaginative world. Those characters primarily grow (level-up) by acquiring unique attributes and abilities via the items they equip in their inventory. Those items, even if defined by the same name and visual depiction, can have uniquely different abilities or attributes. In addition, new, same, or similar items can be created in the game through various vendors within the in-game economy.

Like real world vendors, video game vendors require certain tokens (represented as in-game currency and/or materials) in exchange for the goods they produce for the player. Players then take those items and equip (allocate) them to their character of choice. Credit creation and allocation is functionally decentralized and disaggregated in these games – players will acquire (“farm”) various resources (credit) by defeating enemies in battle or finding treasure and items (“loot”). The role of the central planner in the video game is the video game developer; however, game developers measure the effectiveness and design aspects of credit allocation in their games based on continuous player feedback.

Various game companies have lost considerable business, with their game economies becoming broken or crashed, when disaggregated credit creation is not allocated optimally regarding players’ growth determinants for their characters and interaction with other players’ characters in-game. Here, credit creation, and transitively, the currency (currencies) of the game is a public monopoly of the game’s players. In an analogue relating to RPG gaming and ERC1155, OpenZeppelin (2021) provides the following code example and explanation:

Here's what a contract for tokenized items might look like:

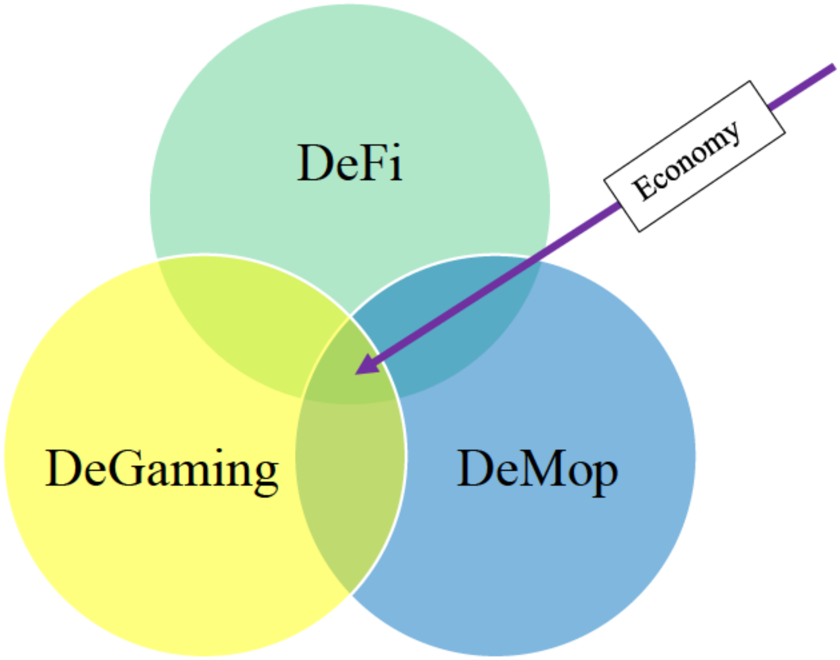
```
// contracts/GameItems.sol
// SPDX-License-Identifier: MIT
pragma solidity ^0.6.0;

import "@openzeppelin/contracts/token/ERC1155/ERC1155.sol";

contract GameItems is ERC1155 {
    uint256 public constant GOLD = 0;
    uint256 public constant SILVER = 1;
    uint256 public constant THORS_HAMMER = 2;
    uint256 public constant SWORD = 3;
    uint256 public constant SHIELD = 4;

    constructor() public ERC1155("https://game.example/api/item/{id}.json") {
        _mint(msg.sender, GOLD, 10**18, "");
        _mint(msg.sender, SILVER, 10**27, "");
        _mint(msg.sender, THORS_HAMMER, 1, "");
        _mint(msg.sender, SWORD, 10**9, "");
        _mint(msg.sender, SHIELD, 10**9, "");
    }
}
```

Note that for our Game Items, Gold is a fungible token whilst Thor's Hammer is a non-fungible token as we minted only one.

Analogously, the model of decentralized disaggregated credit dynamically in this paper replaces the fungible token "Gold" with "credit (money) creation" and "Thor's Hammer" with the non-fungible "Type or Sector of Credit Allocation".

In essence, an economy, regardless of scale, is analogous to the design of an RPG game. RPG games treat tokens as the player's inventory; thus, a real-world economy in this paper's modeling approach treats bank credit creation tokens as the economy's (public's) inventory and 1 to 1 mapping of credit allocation (equipping items) as leveling up community's (characters) stats (economic growth). Any modern real-world economy is, or will become, the functional intersection and degree of decentralized finance ("DeFi"), decentralized monetary policy ("DeMop"), and decentralized gaming ("DeGaming"):

The Modern Real-World Economy



What happens when an economy becomes too saturated and underperforming with misallocated C_F, or worse, crashes because of it? Since RPG game design is analogous to central bank policy design, they both as central planners implement essentially the same protocol: a patch to the system. The patch entails central planners purchasing the bad debts and non-performing assets from the banks within the system, which causes a reflationary economic recovery due to the new credit creation resulting from the purchase. Both central planners although their form factors are different, are engaging in a simple ledger (data array) transaction that erases debt which is at no marginal cost to their players (taxpayers). If central planners instead decided to rebalance their ledgers by imposing marginal costs to their players, players will leave the game (unemployment), exhibit discontent (protest), digital vendors (banks) within the game to go bust while running the risk of the game developer (central planner) to go bust along with it. Central planner examples of this phenomena include, but are not limited to, the German Reichsbank and Blizzard's real money auction-house in their video game Diablo 3 (Moore, 2013). (Although the author did not live during the time of the Reichsbank, the author was alive when Diablo 3 was released and played it while witnessing the economic rise and fall of the auction house within the game).

Put simply, both central planners are resetting the digital scorecard (ledger). Then, the central planners can implement new protocols on the reset system. This process is iteratively repeated over and over again in the hopes of further improving the robustness and antifragility of the game (economy) to improve all the players' experiences (quality of life). Overall, the cyclical development process of any economy or RPG game is: play-patch-repeat to grow, or as gamers colloquially define it, "get good." Gamers have a deep intuition of central planning and institutional design because their investment in gaming allows them to interact in diverse iterative dynamic disequilibrium simulations of disaggregated credit creation and allocation.

A unique feature of ERC1155 is the double mapping of unique token id's, meaning that minted items in games (specific credit allocation types) can be specifically identified with an address, assigned a credit value, and cannot be tampered with allowing both efficient information flow (efficient allocation) and transparency. Below is the specific code from Enjin's GitHub repository, https://github.com/enjin/erc-1155/blob/master/contracts/ERC1155.sol , indicating how this double mapping works with the ERC1155 smart contract:

```
// A sample implementation of core ERC1155 function.
contract ERC1155 is IERC1155, ERC165, CommonConstants
{
    using SafeMath for uint256;
    using Address for address;

    // id => (owner => balance)
    mapping (uint256 => mapping(address => uint256)) internal balances;

    // owner => (operator => approved)
    mapping (address => mapping(address => bool)) internal operatorApproval;
```

Initial Development, Testing, Optimization and Deployment Considerations

This section focuses on a brief overview of how the institutional design of this paper could be executed in the real-world.

Initial Development

The author is currently working on a proof-of-concept prototype of the tokenization of credit in the model proposed in this paper. However, other institutions and individuals are also working on economic prototypes using various token standards. For institutions, while an initial first step will inevitably be prototyping exclusively in-house, the next advisable step would be to consider investing in onboarding technical private sector human capital within the blockchain sector in a collaborative dev-ops environment. This paper views banks as public-private utilities wherein credit creation is the unit of energy for economic growth while the currency itself is a public monopoly. As such, a collaborative development approach between public and private sector should be beneficial to the development process.

Testing

A simple random sample of communities and their corresponding banks should be helpful. Furthermore, the sample should be carefully framed to ensure that variables are not confounding while addressing the unique compositional characteristics of communities. A control group will be necessary and considerations regarding if the testing should be single, double, or triple blind. Most crucially, preregistration of research is of critical importance to establish in order to reduce bias, as indicated by Mertens et al., (2019):

> Preregistration refers to the specification of a study's hypotheses, methodology, and statistical analyses before inspecting the research data. Preregistration takes typically the form of a document that is made publicly available on a timestamped repository or website… (p. 338)

Deployment Considerations

Based on the empirical evidence and statistical significance resulting from testing, it may be prudent to deploy this model gradually, rather than all at once. Inevitably, the programs, and non-computational aspects, within the system will have bugs and require fixes. The deployment and ability to fix problems when they occur should be both agile and flexible.

Potential Design Optimizations

A potential optimization to the proposed network and institutional design of this paper entails finding a creative way to integrate content-addressing using the peer-to-peer InterPlanetary File System (IPFS) protocol. However, further detail regarding the pros and cons of this protocol is beyond the current scope of this paper, but potential efficiency value is worth referencing.

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