Money Supply for a Utility Cryptocurrency*

Antonia Díaz,[a] Gonzalo F. de-Córdoba[b] and Luis A. Puch[c†]

[a]Universidad Carlos III de Madrid
[b]Universidad de Málaga
[b]Universidad Complutense de Madrid and ICAE

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Abstract

Existing literature on virtual currencies takes Initial Coin Offerings (ICOs) as given. However, we are witnessing in recent times a widespread use of ICOs to raise funds from investors. In this paper, we characterize the ICO that sustains an equilibrium allocation under a decentralized two-sided market. Precisely, we show in a model economy where a digital platform allows for decentralized trade, that the time span until the projects matures determines whether the evolution of inflation (i.e., the fall in the exchange rate of the cryptocurrency with respect to legal tender), and the amount of cryptocurrency holdings that agents are willing to accept are mutually consistent. In particular, we show that agents are willing to hold crypto with zero inflation in the long run if, during the transition, inflation has been sufficiently high relative to agents' discount factor.

Keywords: Cryptocurrency, decentralized two-sided markets, money supply.
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†Corresponding Author: Gonzalo Fernández de Córdoba; E-mail: decordoba@genexies.net

1 Introduction

In 2017 we started to witness a widespread use of Initial Coin Offerings (ICOs) to raise funds from investors. The ICOs have been often created to ease the functioning of a decentralized market connected through a digital platform. The success of cryptocurrency's offerings has been quite unequal though. For instance, about 50% of the ICO projects announced in Q2 of 2018 were not able to attract more than USD100,000, which illustrates on a worsening of the projects with respect to 2017 as discussed by Mironov (2018). Here we focus our attention to the interplay of the offering protocol design and market growth in determining the success of an ICO. Our goal is to give conditions for the crytpocurrency's adoption process to be consistent with the market needs. This is important because it is key to disentangle whether a fault is due to the failure of the underlying business model or to the protocol design.

To focus on the interaction between market activity and a virtual currency that supports it, we consider a model economy where a *two-sided platform* develops a cryptocurrency payment system with an intended purpose to provide access to an infrastructure or service via the blockchain. A decentralized two-sided market emerges when there is a large set of buyers and sellers that want to trade an homogeneous product. Examples are personal services like elderly care, teaching, delivery of goods, conversation exchange, passengers transport in automobiles, video editing, games, social media, home exchange, and many other trades where network effects are present. Some of these two sided markets are also supported by a cryptocurrency with which production can be arranged in Decentralized Autonomous Organizations.[1] However, most cryptocurrencies support either pseudo-decentralized organizations like Maker and Augur, or fully centralized like BinanceCoin.[2]

The cryptocurrency we consider is treated as a Utility Cryptocurrency. That is, a virtual currency intrinsically useless outside the two-sided platform, but convertible in fiat as far as an exchange supports convertibility. Notice that fiat money has two defining characteristics, *inconvertibility* meaning that the issuer does not promise to convert money into anything else, and *uselessness* meaning that fiat money is never wanted for its own sake (see Wallace, 1978). At the ICO, there is no promise that the cryptocurrency token will be convertible into fiat. That is, the issuer is not committed to constitute an exchange where the token can be converted into something else at any

[1] For a full list check https://coinmarketcap.com/. For a taxonomy of cryptocurrencies https://www.cryptocompare.com/media/34478555/cryptocompare-cryptoasset-taxonomy-report-2018.pdf

[2] See https://makerdao.com/en/, https://www.binance.com/en, and https://www.augur.net/.

rate. Therefore, the token is money in the usual sense of fiat money. Nevertheless, some ICOs have issued tokens under different conditions transforming the crypto into something else, and how much else depends on the particular conditions of issuance. In this paper we describe the usual type of cryptocurrency issuance though, that is, useless outside the platform and not convertible.

On the other hand, one of the most striking consequences of the adoption of digital platforms is that they allow to overcome the effects of information and search frictions and reduce the minimum scale of production of providers. This has at least two consequences. First, the use of a digital platform allows market participants to share the same information, and to price equally goods that share the same characteristics, time, and location. Second, it incentivizes competition since firm size is not a deterrence to entry. Notice that the use of a digital platform brings, potentially, huge welfare gains for all market participants. These gains, however, depend critically on the number of agents (i.e., market size) channeling their trade through the platform. This is so because the easing of frictions needs, fundamentally, of the interplay of a sufficiently large number of traders.

In this paper we show in a model economy where a digital platform allows for decentralized trade, that the time span that takes from the launch of the ICO to the maturity of the project determines whether the evolution of inflation (i.e., the fall in the exchange rate of the cryptocurrency token with respect to legal tender), and the amount of cryptocurrency holdings that agents are willing to accept are mutually consistent. Trade is decentralized in the sense of Buterin (2017); i.e., the platform allows for *architectural*, *political* and *logical* decentralization.[3] The token is then the reward for the platform promoter. In particular, we show that agents are willing to hold crypto with zero inflation in the long run if, during the transition, inflation has been sufficiently high relative to agents' discount factor. Also, we characterize the ICO that sustains the described allocation, and we illustrate this characterization on a numerical example.

The classic two-sided platform analysis considers a profit center on top of financially neutral participants. Then, different business models or membership structures allow to compare end-user surpluses on both sides of the market. In our case, however, the design of the Initial Coin Offering (ICO) is a key ingredient of building a successful platform. The fact that trade and exchange are decentralized makes the digital platform unsuited to extract any network rents. Moreover, we abstract from any competition between platforms, or from intraplatform competition [cf. Nikzad,

[3]Architectural decentralization is about the number of nodes and a measure of the robustness to failure, political decentralization refers to the number of decision makers, and logical decentralization refers to the morphology of the data structure; see also San Martín (2018) and Rauchs et al (2018) for more details on these issues.

2017]. Our environment is one in which a digital platform provider can obtain its vesting precisely as the result of a successful ICO. It is precisely the successful ICO that guarantees the decentralized functioning of the platform, in contrast with models of platform competition à la Rochet and Tirole (2003). In our setting network externalities are likely to be internalized, and they are not a reason for oligopoly markets as claimed for instance in Economides (1996).

The emergence of cryptocurrencies-supported two-sided platforms bear important consequences for the overall economy. For example, *the traditional firm disappears:* The relation between the participants and the platform is more like that of the members of a club that is governed by its own rules. Also, the traditional relationship between workers and the owners of capital gets broken because the payment is not made trough legal tender. Legal tender presented at a purchase implies an unconditional offer to enter into a contract that accepts all laws, codes and statutes with the force of law. This implies that if the platform is intended to break any law, code or statute applicable at the point of trade, then it has to be made in something different than legal tender. In other words, a cryptocurrency is not a binding medium for the fulfilment of a transaction between parties and therefore any merchant or beneficiary may refuse virtual currencies as a means of payment in most countries (see Law LoC, 2018). As a direct consequence there is a *decentralization of production:* Once the platform operates and the ledger is automated trough the block chain, no one can stop the transactions, because there is no owner.[4] These changes in the organization induce *changes of the fiscal subject:* Investors buy the cryptocurrency in exchange of fiat to make the platform work. But the platform has no fiscal address. Finally, at the same time, there is a *reduction in operational costs:* Tokens eliminate the cost of registering every transaction in the Arrow-Debreu sense. The state of the ledger is maintained by the blockchain and the process of price-setting may be completely decentralized, distributing the cost of maintenance.

The paper is organized as follows: Section 2 describes the typical functioning of a two-sided economy, together with some general ideas about the ICO and both the supply and the demand of cryptocurrency. This includes a brief discussion on the key ingredients of the environment, namely, the matching technology and the business plan underlying transactions. Section 3 presents the benchmark model economy we consider to describe investors' participation in an ICO. Section 4 discusses the findings and Section 5 concludes.

[4] A coordinated attack could take the service down, so "no one" really means no single one.

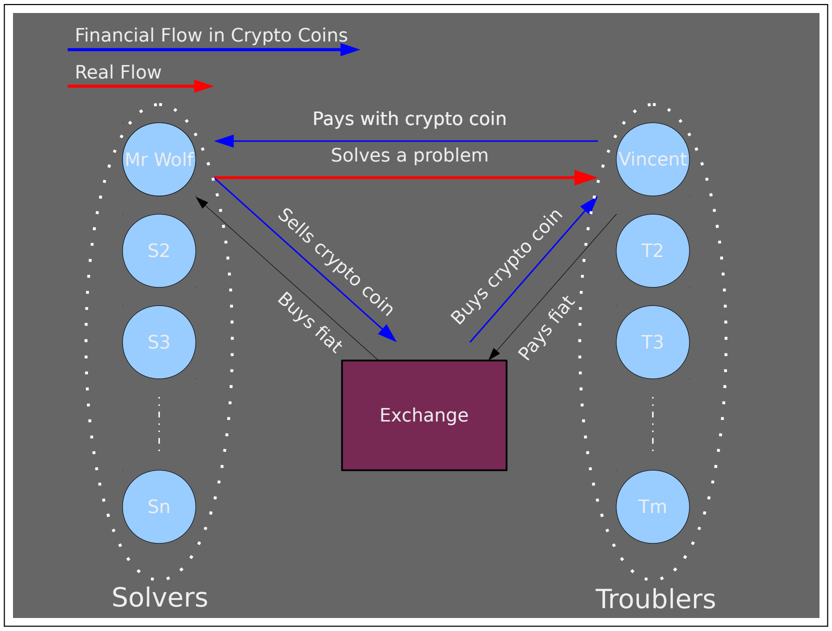


Figure 1: Sideblock's schematics (1)

2 The decentralized two-sided economy

In this section we describe the functioning of a decentralized two-sided economy.

2.1 Market participants

Suppose that a (fictitious) *Sideblock Foundation* launches a platform to provide a communication channel between the two parties of a two-sided economy, *troublers* and *solvers*. The former is the party that demands a service. This service could be a car ride, receiving a hug, or a request for a missed delivery. The solver is usually a person, but it could also be a thing (like the pickup points where a parcel is deposited), or a combination of a person and a thing, like the ride-sharing market where the solver is a driver who puts her own car at the service of the platform.[5] A mobile software implementation matches a troubler with a solver. As we have argued in the Introduction, here we take as given that Sideblock has chosen to run the platform with a cryptocurrency instead of legal tender, and we focus on the functioning of the two-sided economy. Therefore, the key element is that the troubler pays the solver in cryptocurrency in exchange for the service rendered. Moreover, holders of cryptocurrency can exchange it for legal tender in the corresponding market, to which

[5]Or the Solver can even be an API (Application Programming Interface), supporting a software developer *solver*.

we will refer as the *Exchange*.

A summary description of these participants and how they interact is given in Figure 1. For instance, if the solvers $\{S_1, S_2, \ldots, S_n\}$ are persons like Mr. Wolf and the troublers $\{T_1, T_2, \ldots, T_m\}$ are persons like Vincent, we can think of the market as one where the troublers have very dirty cars and the solvers are cleaners of cars. Figure 1 describes also the financial flow of crypto coins backing the real flow of goods or services, together with the flow of exchange to fiat from both solvers and troublers. That is, the trade activity is mirrored by the corresponding activity in the exchange market every period.

For simplicity, we label the cryptocurrency as *token*, whereas the fiat currency will be referred to as *euros*. Therefore, trade between the different participants will be facilitated by the token whose units will be denoted by $\wp$. Those tokens are used by Sideblock Foundation to develop a decentralized economy in which the different players interact directly among themselves. Vincent has a transactions motivated demand of tokens. Mr. Wolf, after being paid in tokens, has two options: he can exchange his token holdings for euros in the exchange market or he can keep them. Thus, he supplies tokens and/or he demands tokens for speculative motives. The only reason to keep the intrinsically useless token is to take advantage of foreseen future appreciation of the token against the euro. Additionally to these demands and supply of tokens, Sideblock participates in the *Exchange* to swap tokens for euros to pay for platform maintenance and capital depreciation.

Sideblock connects a troubler with a solver trough an App that allows them to set a price and acknowledge the delivery of a solution. That is, the digital platform eliminates all search and matching frictions in the trade activity, and the clearing of the exchange market determines the price of a euro in units of token, q_t. Notice that the use of a cryptocurrency ensures that Sideblock cannot extract any rent from solvers and troublers. In fact, Sideblock renounces to any network rents in the future, and obtains its vesting as the result of a successful Initial Coin Offering (ICO). Consequently, the ICO guarantees the decentralized functioning of the platform in the sense of Rochet and Tirole (2003), as discussed in the Introduction. Moreover, the use of a cryptocurrency acts as a commitment device.

2.2 Market activities

It is useful to think of this two-sided economy as a small open economy where the official currency is token, the main activity is intermediated by a digital platform, and the domestic currency (tokens) can be traded for foreign currency (euros) in the market labeled *Exchange* in Figure 1. The small open economy paradigm is useful because it allows us to think of variations in the real value of the token as changes in the real exchange rate of the economy. On top of that, the real return to capital is given by the international market. In this small open economy abstraction, Sideblock is the market designer. First, it ensures that the platform runs so that the real activity can take place by matching troublers and solvers. Second, it designs and oversees the launching of the Initial Coin Offering of tokens, which comprises the money supply of this small open economy. Sideblock retains, as vesting, a fraction of ICO, during a fixed period of time. There is a key third activity which is completely decentralized: the traceability that solves the problem of double spending. Obviously, the three market activities affect one another. The problem inherent to this two-sided economy is that Sideblock Foundation is creating two markets at the same time: the market where real activity takes place and the exchange market. Thus, its problem is intrinsically dynamic: Sideblock has to ensure, from an ex-ante point of view, that, as the real market becomes thicker (i.e,: more troublers and solvers enter the market), there is enough liquidity of tokens according to some particular criterion and, obviously, that the exchange market functions.

Nevertheless, this two-sided economy is not a conventional small open economy. The reason lies in that tokens are fundamentally different from euros (or any other legal currency). However, the difference is not that tokens are not legal tender; i.e., the fact that tokens are not recognized by a legal system to be valid for meeting a financial obligation. That recognition is not needed in the digital era. The key difference instead is that tokens are not accepted by a fiscal authority as a legal means to comply with fiscal obligations. While there are no taxes in the market activities we consider in this paper, it is good to keep this distinction in mind. In particular, this is one of the reasons why cryptocurrencies have become so attractive in the real world.

In what follows we are going to assume that Sideblock has access to a technology that ensures that no agent can manipulate the digital currency token. The correct functioning of this technology is a necessary condition for the two-sided economy to work in a decentralized manner: agents need to trust that tokens cannot be counterfeited; i.e., the fact that the same token cannot be used in

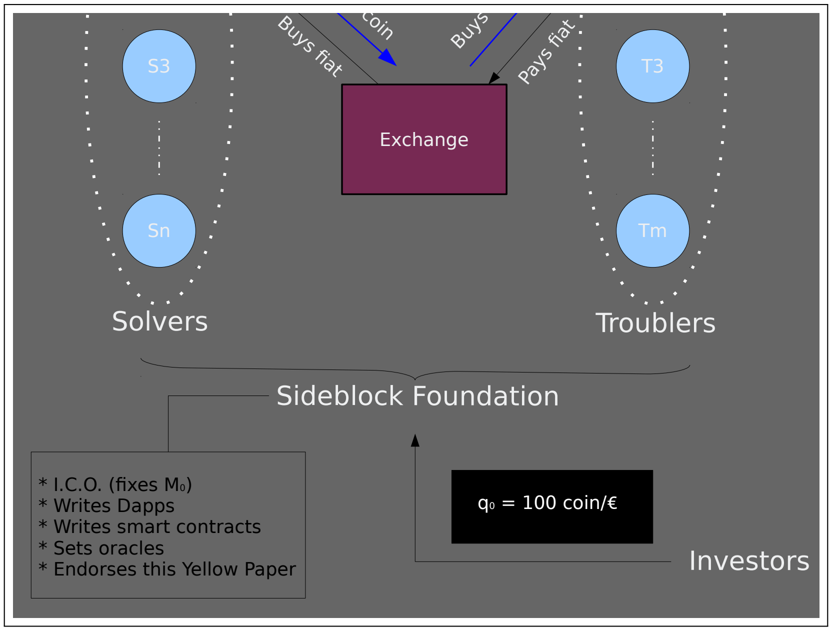


Figure 2: Sideblock's schematics (2)

two different transactions. We further take as given that the exchange market functions perfectly as a Walrasian market. For this we need to assume that the digital platform works smoothly and that the size of the market of real activity evolves over time according to a particular dynamics that we will specify in Section 2.4.

Summarizing, we have described a particular two-sided environment, and some important assumptions on the market activities, namely: *i)* decentralized trade and exchange, *ii)* cryptocurrency use, traceability, and trust, and *iii)* Walrasian exchange. Given the described environment and the aforementioned assumptions, the key issue is how the monetary policy is conducted: That is, how the Initial Coin Offering is designed and how the token supply target is achieved thereafter.

2.3 The design of an ICO and the Investors

By definition, an Initial Coin Offering (ICO) is issued at the time zero of the two-sided economy: that is, when the digital platform starts and the exchange market is created. The ICO is issued by the Sideblock Foundation and exchanged by euros that will be used to start up the digital platform, and platform maintenance, among other. The agents who buy the initial offering of tokens will be called *investors*. Figure 2 highlights how investors enter the two-sided economy to provide financial support to Sideblock Foundation's duties[6].

It is important to emphasize that Sideblock, as the market designer, can issue this ICO but it is forbidden from changing the token supply ex-post; i.e., Sideblock cannot use open market operations to change the monetary base later on. An ICO will find investors whenever it ensures a sufficiently high expected return to their investment in euros, which depends critically on the evolution of the exchange rate token-euro. As a matter of fact, investors want the token to appreciate as much as possible. On the other hand, the stable functioning of the two-sided platform in the long run needs of a stable exchange rate or, at least, one with a stable appreciation pattern. Thus, Sideblock has to weigh the two goals in its objective function when designing the ICO.

Precisely speaking, at time zero Sideblock writes a *yellow paper* which specifies *i)* a business adoption plan, and *ii)* the ICO, with the specification of M_0 and initial price of euros in token, q_0. The evolution of the exchange rate token-euro will depend first on the growth rate of the real activity. In section 2.4 below we describe a market activity with a particular pattern: it grows at a higher rate than the overall economy (i.e., the rest of the world, in the convention of the small open economy literature) during a transitory period (which can be very long) and settles to grow at the same rate than the rest of the economy in the long run.[7]

The second key element in the yellow paper is the initial token demand. As in any other monetary economy, there are two motives to hold tokens: a transaction motive and a precautionary, in this case, speculative, motive. Investors lend the amount M_0/q_0 in euros and receive the amount M_0 of tokens. The return of their investment is linked to the appreciation pattern of the token. The design of the ICO is not trivial. The fact that open market operations are ruled out implies that if the business adoption plan is too optimistic Sideblock cannot withdraw liquidity from the market, which will affect the exchange rate q_t and reduce the return due to investors.

In the model economy we propose agents have rational expectations about the business plan adoption. There we characterize the conditions under which an ICO is successful. Let us be precise next on the business adoption model.

[6]See Teutsch et al (2017) [14] where an auction is described in an adversarial environment

[7]This abstraction, while theoretically harmless, presents some technical problems, (see Song, 2018), as to determine the appropriate oracles to provide the required input about relative growth rates and tuned with the appropriate smart contracts that keep the exchange rate stable.

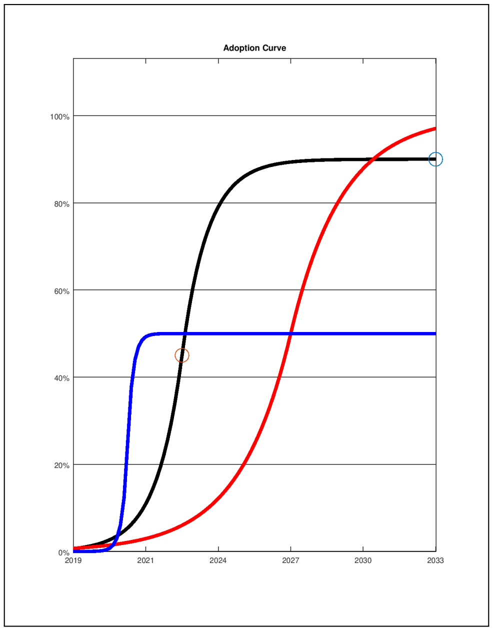


Figure 3: The business plan as an adoption curve

2.4 The business adoption model

Given an ICO and the evolution of the supply and demand of tokens, the exchange rate, q_t, will depend critically on the growth of the number of transactions (business volume) and on the expectations about its future growth rate. In principle, forecasting the evolution of the business value is a difficult task. To attract investors, Sideblock presents a business plan where the investors are informed of the prospective evolution of the business. A simple representation of such a business plan displays a transitional phase along which an increasing number of participants is expected to incorporate, and thus, a rising share of the market is intermediated by the digital platform during that phase. After a number of periods, the market share is expected to remain constant. This is what is called *a business adoption plan.* We formalize a business plan with a three parameter adoption function as the one represented in Figure 3 [cf. Burniske, 2017]. Precisely, the adoption function can be parameterized as:

$$F(y) = \frac{\eta}{2}\left[1 + sgn(y-\mu)\left(1 - e^{\frac{-\sqrt{2}}{\sigma}|y-\mu|}\right)\right] \tag{2.1}$$

The three parameters are the market share where it settles in the long-run steady state η, the inflection point where the market starts to mature μ, and the speed of convergence to the steady state σ. The amount of tokens in full supply is a function of the target. Thus, if the steady state is reached at time T, the amount of money in circulation has to be equal to the market value in fiat of the transactions in the market. If the computed amount of money at T corresponds to the highest η (red) line, but the observed one is that of the lowest η (blue) line, then there would be too much money in circulation, and the exchange rate to fiat will never reach the target, say parity $\equiv q_T = 1\frac{\wp}{\text{€}}$, for instance. The other two parameters are related to the speed of convergence to the steady state, and are therefore of second order of importance. Nevertheless, we will see below that any calibration is non-standard, in the sense that we need to forecast the growth of business (i.e, a parametric adoption curve).

In the rest of the paper we present a model economy that has the main features of the two-sided economy we have described. In such a setting, we study the aggregate and price effects of different ICOs depending on the evolution of the real activity. We assume that Sideblock values long run price stability and that, in the long run, the exchange rate of tokens stays constant, as the economy converges to a balanced growth path. The return of investors depends critically on the evolution of the appreciation of tokens along a transition path and its length.

3 The Model

This is is an infinite horizon economy populated by infinitely lived agents. Time is discrete and there is perfect foresight.

3.1 The Solver's problem

Once we have determined the participants in the token market we show how to compute the ICO such that the adoption curve is satisfied and the desired exchange rate of the euro-token is obtained as an equilibrium.

We first start modeling the solvers' problem. The Solver, w, works in the package delivery industry that will be (partially or completely) replaced by Sideblock. The endowment of time is a fixed quantity of working hours L that are used in ether technology. The traditional delivery system pays an hourly wage of w_t euros per package.[8] The income of a Solver that devotes l_t hours in Sideblock, receives a payments of $w_t l_t$ measured in Token ($\wp$). Therefore, the amount of time devoted to the traditional delivery industry is $(L - l_t)$ hours, that receive a payment of $q_t w_t$ per hour, and expressed in fiat.[9] The goal of the stand-in Solver is to maximize the discounted stream of current and future consumption

$$\max_{\{c_t, l_t, m^{\mathrm{w}}_{t+1}\}} \sum_{t=0}^{\infty} \beta^t U(c_t)$$

Subject to:

$$s_t + m^{\mathrm{w}}_t - m^{\mathrm{w}}_{t-1} = w_t l_t + q_t w^e_t (L - l_t)$$
$$\frac{s_t}{q_t} = c_t$$

Each solver has an endowment of time L that can be devoted to work. The Solver can split her endowment of time working l_t hours in the platform and $L - l_t$ in an alternative market. Where w^e_t is the hourly wage paid in the market on a similar work. Therefore, arbitrage in the labor market produces the following equality: $w_t = q_t w^e_t$. Substituting the arbitrage labor condition, we get that the stand-in solver has resources with a value of $q_t w^e_t L$ which is the total value of the time endowment expressed in tokens.

The budget constraint states that all income from working serves to finance two activities: one is to increase (to hold) the stock of tokens $(m^{\mathrm{w}}_t - m^{\mathrm{w}}_{t-1})$ or to move the tokens to the market to exchange $\wp s_t$ into consumption of goods and services. Since the rest of the goods of the economy are denominated in fiat, the amount of tokens has to be divided by the exchange rate to transform it into purchasing in fiat. That is the meaning of the second constraint

An important element of our analysis relates to the structure of the discount rate of solvers. The parameter β, tells us how impatient the stand-in solver is. If $\beta = 1$ the Solver is absolutely patient. If the Solver has the expectation of a future revaluation of the cryptocurrency against fiat, then the Solver will hold large amounts of the token in order to move their wealth into the future. On the contrary, if the value of $\beta = 0$ the Solver is extremely impatient, and he/she will transform

[8] Assuming that there are a fixed number of packages that can be delivered per hour, to measure the wage in hours or packages is the same.

[9] We are assuming here that the nominal payment is the same just to save notation. This problem becomes relevant as a participation constraint, where the payment in Token ($\wp$) has to translate to at least the value in fiat that the Solver get when working for the traditional industry.

any earned token into fiat no matter what are his/her expectations about future developments on exchange rates.

The optimality conditions for the Solver are given by:

$$\beta^t U'(c_t) - q_t \lambda_t^{\mathrm{w}} = 0 \tag{3.1a}$$

$$\lambda_t^{\mathrm{w}} - \lambda_{t-1}^{c} = 0 \tag{3.1b}$$

$$w_t - q_t \overline{w}_t^{e} = 0 \tag{3.1c}$$

$$w_t l_t + q_t w_t (L - l_t) - q_t c_t - m_t^{\mathrm{w}} + m_{t-1}^{\mathrm{w}} = 0 \tag{3.1d}$$

The combination of the first two equations (3.1a) and (3.1b) produce a new equation that together with the budget constraint, form the system of equations that provides a solution to the Solver's problem, provided that the participation constraint (3.1c) is satisfied. This participation constraint states that whenever $w_t^n \geq q_t \overline{w}_t$, the solvers are willing to supply all the labor required by Sideblock, thus the participation constraint places a lower bound to Sideblock's wages. To solve the numerical problem we have chosen a functional form for the utility function as $U(c_t) = \log(c_t)$.

$$\boxed{\begin{cases} \frac{q_t}{q_{t+1}} = \frac{c_{t+1}}{\beta c_t} \\ q_t c_t + m_t^c - m_{t-1}^c = w_t l_t + q_t w_t (L - l_t) \end{cases}} \tag{3.2}$$

In our problem, the sequence of exchange rates $q_t = x_t \wp/€$ is given as a target. The sequences of wages and labor are also given, since they depend on the adoption of a technology that is completely given to the Solver.

We create a sequence of exchange rates that is consistent with the revaluation scheme set as a target. We know the initial exchange rate q_1 because it is fixed at the moment of the initial supply of tokens. Say that we start at $q_1 = 100$, and we want a revaluation that it is initially high, but steadily decreasing to leave a value of $q_T = 1$. Date T is the date when the business plan reaches the market share set as a target.

3.2 The Investor's problem

The problem of the investors, i, is similar to that of the Solver. However, there are some important differences. The investors do not work as a man-in-van delivering packages, and therefore they do not trigger a demand of the token by the Courier. Investors find competing businesses where they can allocate portions of their wealth. For the purpose of our problem, the investors budget constraint can be written as

$$\left(\frac{m_t^{\mathrm{i}}}{q_t} - \frac{m_{t-1}^{\mathrm{i}}}{q_t}\right) + (k_t - k_{t-1}) + (b_t - b_{t-1}) + d_t = \left(r_t^k - \delta\right) k_{t-1} + r_t^b\, b_{t-1} \tag{3.3}$$

Where, b_t is a well diversified portfolio representing the financial assets of the global economy where the Investor is long. Therefore the magnitude $(b_t - b_{t-1})$ is investment, and the value of $r_t^b b_{t-1}$ is the international real return of portfolio b_t. On the other hand, the Investor can invest in real assets of Sideblock. Total net investment is $(k_t - k_{t-1})$ and the return is Sideblock's payment to capital, after taking into consideration the depreciation of the asset is $(r_t^k - \delta)k_{t-1}$ Then, total resources of the investors are $(r_t^k - \delta)k_{t-1} + r_t^b b_{t-1}$ that has to be allocated into an investment in Sideblock assets included its token currency $(m_t^{\mathrm{i}}/q_t - m_{t-1}^{\mathrm{i}}/q_t)$, and the diversified world portfolio of assets after paying a dividend d_t.

Similarly to the Solver, the Investor wishes to maximize a discounted stream of dividends, as

$$\max_{\{d_t, m_{t+1}^{\mathrm{i}}, k_{t+1}, b_{t+1}\}} \sum_{t=0}^{\infty} \beta^t d_t$$

Subject to:

$$\left(\frac{m_t^{\mathrm{i}}}{q_t} - \frac{m_{t-1}^{\mathrm{i}}}{q_t}\right) + (k_t - k_{t-1}) + (b_t - b_{t-1}) + d_t$$
$$= \left(r_t^k - \delta\right) k_{t-1} + r_t^b\, b_{t-1}$$

This problem can be solved with the use of the auxiliary Lagrange equation (with λ_t^{i} as Lagrange multiplier). The set of first order conditions provide the following system:

$$\beta^t - \lambda_t^{\mathrm{i}} = 0 \tag{3.4a}$$

$$\frac{\lambda_t^{\mathrm{i}}}{q_t} - \frac{\lambda_{t+1}^{\mathrm{i}}}{q_{t+1}} = 0 \tag{3.4b}$$

$$\lambda_{t+1}^{\mathrm{i}}(r_{t+1}^k + (1-\delta)) - \lambda_t^{\mathrm{i}} = 0 \tag{3.4c}$$

$$\lambda_{t+1}^{\mathrm{i}}(1 + r_{t+1}^b) - \lambda_t^{\mathrm{i}} = 0 \tag{3.4d}$$

Combining the last two equations (3.4c) and (3.4d) we obtain a non-arbitrage condition between Sideblock's assets and the external asset:

$$r_t^b = r_t^k - \delta, \ \forall t = \{0, 1, 2 \ldots\} \tag{3.5}$$

This equation states that Sideblock's net payment, as return to the Investor's physical capital holding, has to cover the opportunity cost represented by external investments. As long as Sideblock pays more to capital than the external portfolio, it is guaranteed that the investors will desire to invest in Sideblock's assets. Therefore this condition must hold at all times.

Combining equations (3.4b) and (3.4c) we obtain that

$$r_t^k + (1-\delta) = \frac{q_{t-1}}{q_t} \tag{3.6}$$

This equation is a second non-arbitrage condition, and states that the capital gain from holding the currency has to be equal to the return of holding one unit of Sideblock's physical asset, which in turn has to pay at least as one unit of the diversified portfolio.

Combining arbitrage conditions (3.5) and (3.6) we obtain the thresholds under which investors are expected to hold tokens or to sell tokens.

$$\begin{aligned}
&\frac{m_t^{\mathrm{i}}}{q_t} - \frac{m_{t-1}^{\mathrm{i}}}{q_t} > 0 \quad \text{if } r_t^k + (1-\delta) \leq \frac{q_{t-1}}{q_t} \rightarrow \text{ investors hold tokens} \\
&\frac{m_t^{\mathrm{i}}}{q_t} - \frac{m_{t-1}^{\mathrm{i}}}{q_t} < 0 \quad \text{if } r_t^k + (1-\delta) \geq \frac{q_{t-1}}{q_t} \rightarrow \text{ investors sell tokens}
\end{aligned} \tag{3.7}$$

3.3 The Troubler's problem

Solver's activity covers several parts of the delivery process in e-commerce. One of these is to deal with the so called "last mile" delivery. This activity entails to deliver the package from a hub or a warehouse to the shopper. However, time to time, couriers find themselves with a missed delivery that they have to solve. A missed delivery is produced when the courier fails to deliver the package due, mostly, to the absence of the shopper at the moment of delivery.

Missed deliveries generates several costs. First, it discourages e-commerce to shoppers that rarely are at home. Second, those shoppers that buy and experience a delivery failure, have to increase their waiting time for a new try, or to travel to a pick-up point where the parcel is deposited awaiting for the shopper to pick it up. And third, the cost of dealing with the missed delivery by the courier that is valued in €C_{md}.

The adoption of Sideblock's technology has a positive impact on all these costs. But Sideblock's technology will be adopted if and only if some inequalities regarding the price of the services are met. If the courier is to resort to Sideblock's solution, the Courier has to access the exchange and buy a number z_t of token ($\wp$) ($\wp$) such that $z_t/q_t \leq C_{md}$, otherwise the service provided by Sideblock would be too expensive for the courier, who would then prefer to solve the problem by themselves. On the other hand, the price asked by Sideblock has to cover the cost of producing one unit of Sideblock product, which is a solution to the missed delivery. This solution has a labor and a capital cost of $w_t l_t + (r_t^n - \delta)k_{t-1}$ expressed in token ($\wp$). So, there are two participation constraints that have to be met: Sideblock has to cover the cost of producing one unit of service, and this unit has to cost less that the cost induced by a missed delivery handled by the courier.

Figure 4 shows the lower boundary in Sideblock's pricing system. Assume that, for example, €1 is the amount paid by each parcel delivered by a courier. If the courier adopts Sideblock's technology at time $t = 0$, when $q_0 = 100$, then the amount of tokens that the courier has to receive is $q_0 \frac{\wp}{€} €1 = 100\wp$. The arrows pointing at the inner area of the figure, shows that Sideblock's pricing system can be any arbitrary combination inside that set, provided that the cost in tokens does not exceed the amount that the courier is willing to absorb when a missed delivery happens.

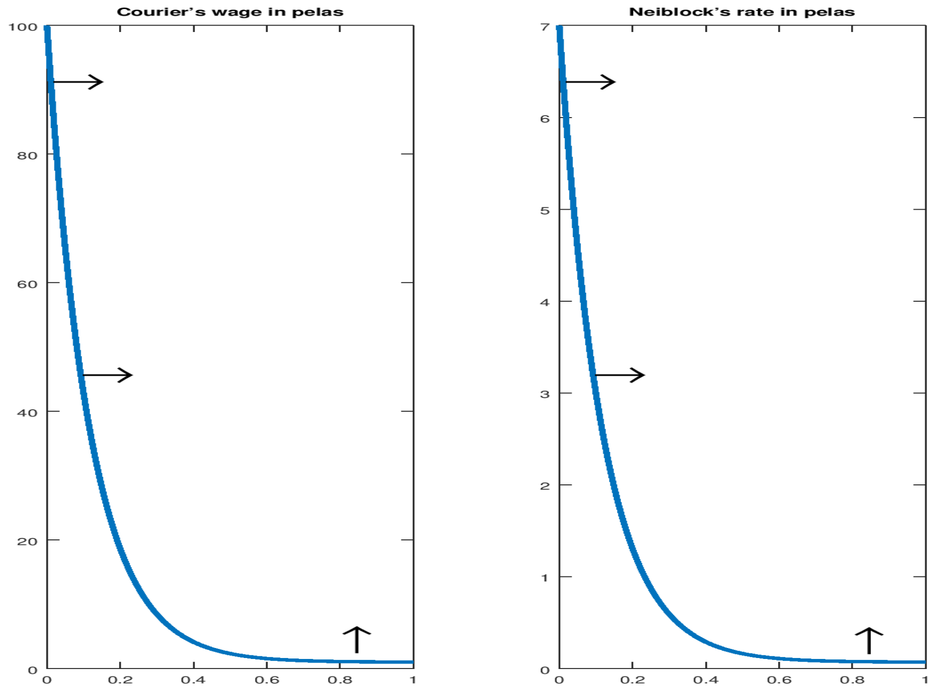


Figure 4: Boundaries of the prices scheme

3.4 Equilibrium and the Sideblock's problem

Sideblock's problem is a special problem given the nature of this agent. Sideblock's governing body has to merge the Solver's problem and the Investor's problem in the Social Planner Problem's sense. Sideblock's plan is to find an allocation such that: i) the allocation is feasible, and ii) the allocation maximizes the individual problems of all the agents. Therefore, all agents not only want to participate, but also iii) they want to follow and stick to the plan because it is in their own interest.

Therefore, Sideblock's problem is:

$$\max_{\{c_t, l_t, m_{t+1}, k_{t+1}, b_{t+1}\}} \sum_{t=0}^{\infty} \beta^t (U(c_t) + d_t)$$

Subject to.

$$q_t s_t + m_t - m_{t-1} = w_t l_t + q_t\, w_t^e (L - l_t)$$

$$c_t + k_t - (1-\delta) k_{t-1} + b_t - b_{t-1} = s_t + r_t^k\, k_{t-1} + r_t^b\, b_{t-1}$$

with b_0 given

This problem, obtained as a merge of the two problems above, provides a Pareto efficient allocation, that is, a collectively optimal allocation with the property that no single group can improve upon it. Notice that $m_t = m_t^{\mathrm{w}} + m_t^i$, all t.

The set of optimal conditions is given by:

$$\beta^t U'(c_t) - q_t \lambda_t = 0$$

$$w_t - q_t\, w_t^e = 0$$

$$\lambda_t - \lambda_{t-1} = 0$$

$$\lambda_t\, q_t (r_t^k + (1-\delta)) - \lambda_{t-1}\, q_{t-1} = 0$$

$$\lambda_t\, q_t (r_t^b + 1) - \lambda_{t-1}\, q_{t-1} = 0$$

$$w_t l_t + q_t\, w_t^e\, (L - l_t) - m_t + m_{t-1}$$
$$- q_t \left(c_t + k_t - (1-\delta) k_{t-1} - r_t^k\, k_{t-1} + b_t - b_{t-1} - r_t^b\, b_{t-1} \right) = 0$$

This set of equations incorporates the optimality conditions of the problems of the solvers and the investors. However, the last equation of this system ensures that the allocation is feasible. The first equation tells us, about the consumption of the solvers if they were as patient as the investors.The sequence of consumption provides us with the lower bound of the money supply provided by the Solver. For a given sequence of future revaluations, we obtain the amount of liquidity needed to sustain the schedule of prices that we want to impose as a solution. The second equation is the non-arbitrage condition between working in the market and working for the two-sided economy. The optimality conditions with respect to the three stocks, $\{m_t, k_t, b_t\}$, produce an exact replica of the dynamic equations that describe the optimal behaviour of the Solver and the Investor presented above.

4 Results

4.1 Money and inflation

Let us write forward the consolidated budget constraint of the two-sided economy in equilibrium, that is,

$$m_t = q_{t+1}\, c_{t+1} + m_{t+1} - q_{t+1}\, w^e\, L, \text{all } t \in\ (0, T).$$

Solving forward the above expression it can be written,

$$m_0 = \sum_{t=1}^{T} q_t\, (c_t - w^e L) + m_T,$$

for T determined by the Sideblock foundation, in a way consistent with the business plan. Since the number of tokens held by the solvers at the beginning of the market is $m_0 = 0$, then,

$$m_T = -\sum_{t=1}^{T} q_t\, (c_t - w^e L)\,, \tag{4.1}$$

and correspondingly,

$$m_T = w^e\, L \sum_{t=1}^{T} q_t - \sum_{t=1}^{T} q_t\, c_t.$$

Notice that the Euler equation with respect to m_t implies $(q_t/q_{t+1}) = (c_{t+1}/\beta c_t)\,$, and therefore, the total amount of tokens held at the steady state can be written as:

$$m_T = w^e\, L \sum_{t=1}^{T} q_t - q_T\, c_T \frac{\left(\frac{1}{\beta}\right)^{T-1} - \beta}{1-\beta}. \tag{4.2}$$

Notice further that in steady state it occurs that $q_T\, c_T + m_T - m_T = q_T\, w^e\, L$, which implies that $c_T = w^e\, L$.

Now we are in the conditions to characterize a successful ICO. Consider the simplest smooth transition for the token revaluation, in the form of a deterministic linear difference equation with parameters ϕ_0 and ϕ_1, precisely,

$$q_{t+1} = \phi_0\, q_t + \phi_1, \text{all } t \in (0, T),$$

that we can solve forward to obtain $\sum_{t=1}^{T} q_t = \frac{q_1 - \phi_0 q_T}{1-\phi_0} + (T-1)$. Thus, we can state the following results,

Proposition 1. *There exists a sufficiently large value of β and a sufficiently high revaluation scheme for q_t such that $m_T > 0$*

Proof. First, look at the second term in the right hand side of equation (4.2) and notice that

$$\beta \to 1 \implies \frac{\left(\frac{1}{\beta}\right)^{T-1} - \beta}{1-\beta} \to T.$$

We have assumed throughout $q_T = 1$, and therefore,

$$m_T \to w^e L \left[\frac{q_1 - \phi_0 q_T}{1-\phi_0} - 1\right]$$

positive iff $\frac{q_1 - \phi_0 q_T}{1-\phi_0} \geq 1$, or $\phi_0 \leq \frac{q_1 - 1}{q_T - 1}$. For any $q_1 > \phi_0 q_T + (1-\phi_0)$ there will be a positive token holding in the steady state. □

The interpretation is clear. If the solvers are sufficiently patient, any revaluation will work. Rather, if the solvers are more impatient, the difference between q_1 and q_T will have to be larger, and ϕ_0 closer to one, so that the accumulated revaluation get sufficiently large.

Proposition 2. *It is possible to find an analytical solution for the Solvers problem, and the solution is:*

$$m_t = m_0 + \sum_{j=1}^{t} q_i \left(w^e L - c_i\right) \quad (4.3)$$

$$c_t = \left(\frac{1}{\beta}\right)^{T-t} \frac{\phi_0^T q_0 + \phi_1 \sum_{j=1}^{T} \phi_0^{j-1}}{\phi_0^t q_0 + \phi_1 \sum_{j=1}^{t} \phi_0^{j-1}} w^e L \quad (4.4)$$

Proof. From optimality it is easy to show that

$$q_t c_t = \left(\frac{1}{\beta}\right)^{T-t} q_T w^e L \quad (4.5)$$

and also, from the exchange equations, that

$$q_t = \phi_0^t q_0 + \phi_1 \sum_{j=1}^{t} \phi_0^{j-1}$$

substituting the last expression into (4.5) we obtain the result for c_t as a function of parameters. The expression for m_t is a forward substitution of previous values of m and it is a function of q_t and c_t for which we have analytical solutions as it has been proved □

Notice that any continuous and differentiable revaluation will deliver the same result. Also, one may consider a distribution of returns with fat tails, so there will be a trade off between revaluation and discount. Finally, one may consider a configuration under rational bubbles. We leave all these alternative approaches for further research.

4.2 A numerical example

4.2.1 Calibration

The calibration is non-standard, in the sense that we need to forecast the growth of business (i.e, a parametric adoption curve). Three parameters govern the adoption curve: *i)* the target market η (governing market size), *ii)* the speed of convergence to target σ (governs growth rate of business relative to the overall economy), and *iii)* the inflection point μ (time of change in growth rate). Across experiments we consider revaluation schemes and time horizons for the ICO that are consistent with a particular configuration of these three parameters of the business adoption plan.

We also need three parameters for the Solver: *i)* the preference parameter β, *ii)* the hourly wage w, and *iii)* the exchange rate against the euro at the long-run equilibrium q.

Two parameters and two values of the exchange rate govern the evolution of the revaluation scheme. Given q_0 and q_t, we can obtain the parameters ϕ_0 and ϕ_1 that satisfy a smooth convergence from q_0 to q_T. Finally, it is requested a yearly prediction from Augur for steady growth of output.

According to the simple revaluation scheme above we have that $q_{ss} = \phi_0 q_{ss} + \phi_1$, or

$$q_{ss} = \frac{\phi_1}{1 - \phi_0}$$

Fixing $\phi_1 = 1 - \phi_0$ we ensure a value of $q_T = 1$. We can also determine the initial expected appreciation of the exchange rate r_0 so that using all the information we can write,

$$\frac{q_1}{q_2} = r_0$$

$$q_2 = \phi_0 q_1 + (1 - \phi_0),$$

where r_0 is a key parameter, and we obtain a value of

$$\phi_0 = \frac{q_1/r_0 - 1}{q_1 - 1}$$

with which we get a desired initial appreciation that will steadily decrease to 0 leaving the exchange rate in the desired value of $q_T = 1$. If we fix as an example $r_0 = 1.09$, we can ensure that with a $\beta = 0.96$ some tokens will be held by solvers.[10] Since the return to the token has to fall in the steady state to a level of zero, we ensure that the Solver will show a desire to hold the token at the beginning of the adoption plan, and will want to sell by the end of the adoption period.[11]

Figure 7 shows the dynamics of money holdings by investors and the $\wp$/€ exchange rate. While the rate of appreciation of the token exceeds the opportunity cost of holding a unit of the international portfolio, all tokens are held by investors. Once the point where both rates are equal, investors are willing to undo their position on the token and proceed with a mass sale. This sale, however, has the effect of depreciating the value of the token, making it jump above the original revaluation path. While the adoption of Sideblock's technology keeps expanding, a new impulse of revaluation follows, resulting in a desire of holding the remaining tokens while their revaluation exceeds the rate paid by the international portfolio. The same logic applies to the second sale by investors, and to the third with a mitigated impulse as more tokens are on the market.

4.2.2 Simulation

Proposition 1 states under which conditions an ICO could be successful, and therefore also states under which conditions it can fail. Here we show how a delayed appreciation of the token and

[10] This value of β is consistent with a subjective discount of $\theta = 1/\beta = 1.04$. That is, immediately after the sale of tokens, the revaluation of the tokens (1.09) will be higher than the subjective discount factor (1.04), and therefore the solvers would be willing to hold the token until the token's return falls below the subjective discount rate.

[11] The pattern of consumption at the left and at the right of the point where θ and q_t/q_{t+1} cross will also be different as we can see in Figure 5

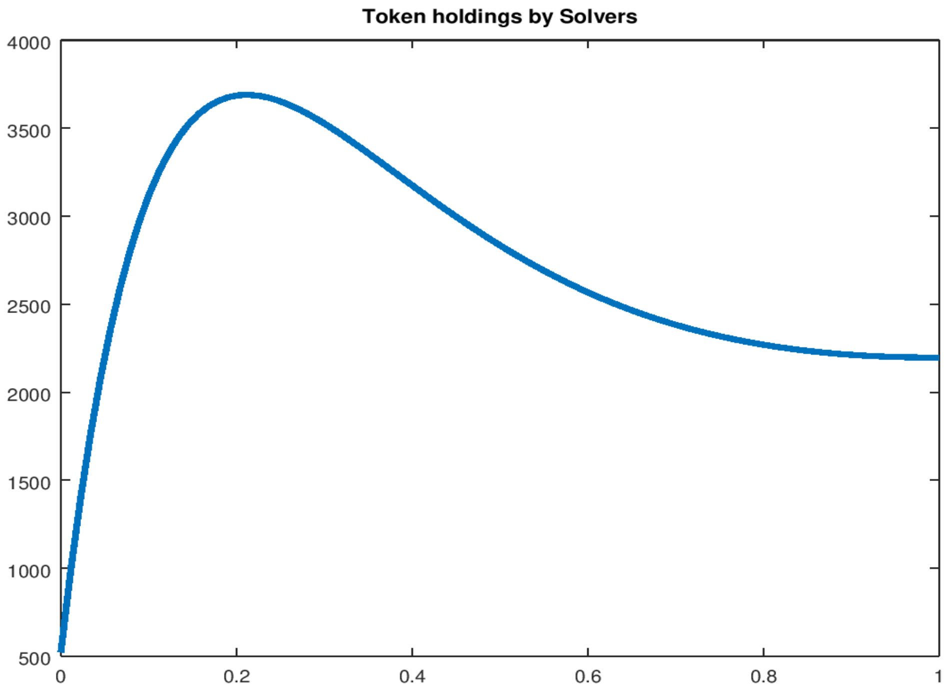


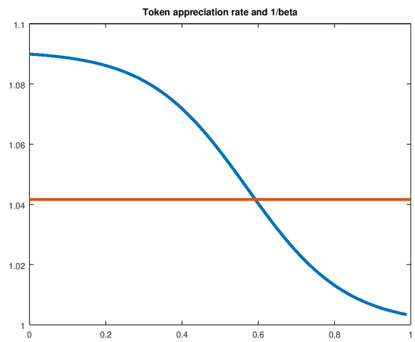
Figure 5: Solver's money holdings in the adoption period

impatient Solvers can lead to a failed ICO where market participant would desire to have negative holdings (short sale) of the token

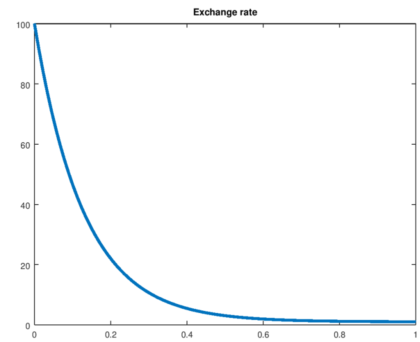
Finally, it is important to notice that velocity is trivially computed from the results stated in propositions 1 and 2 as a residual. In our model velocity is obtained from the behavior of maximizing agents.

In our view, velocity is a response of a system made of agents who's will is governed by economic motives, and these motives make them keep an optimal cash-balance. As we can see in figure 9, in the early stages of the development of the business, velocity falls because of the high capital gains derived from holding money, while not too many transactions take place. Later, the process is reverted as gains decrease and trade increase until velocity reaches a maximum, then it settles to a velocity that is only explained by transaction motives.

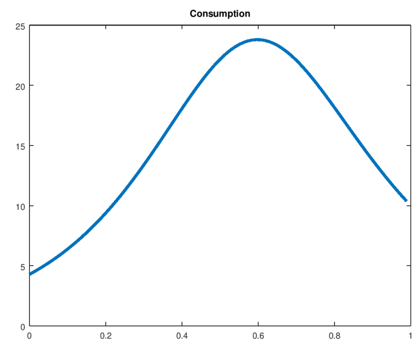
The cash-balance theory is not the only one that has been put forward to explain velocity, see Holtrop (1929) for a comparative discussion. It is, however, the one that results from our choice of model. A different model, e.g. a model of matching agents in a two-sided market, would imply



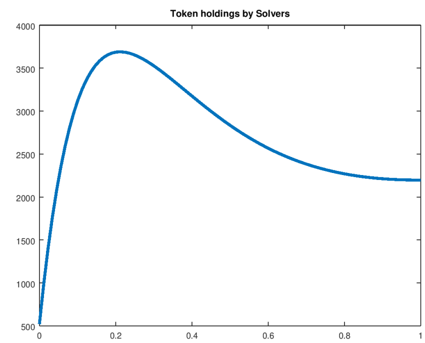
(a) Capital gains and $\frac{1}{\beta}$



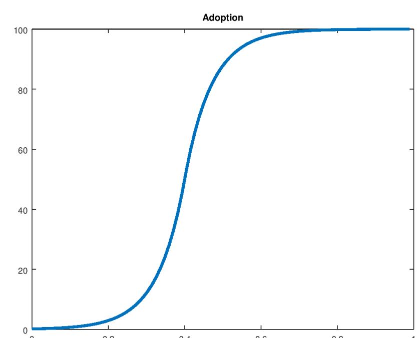
(b) Exchange rate



(c) Consumption



(d) Token holdings



(e) Adoption curve

Figure 6: The Initial Coin Offering (ICO).

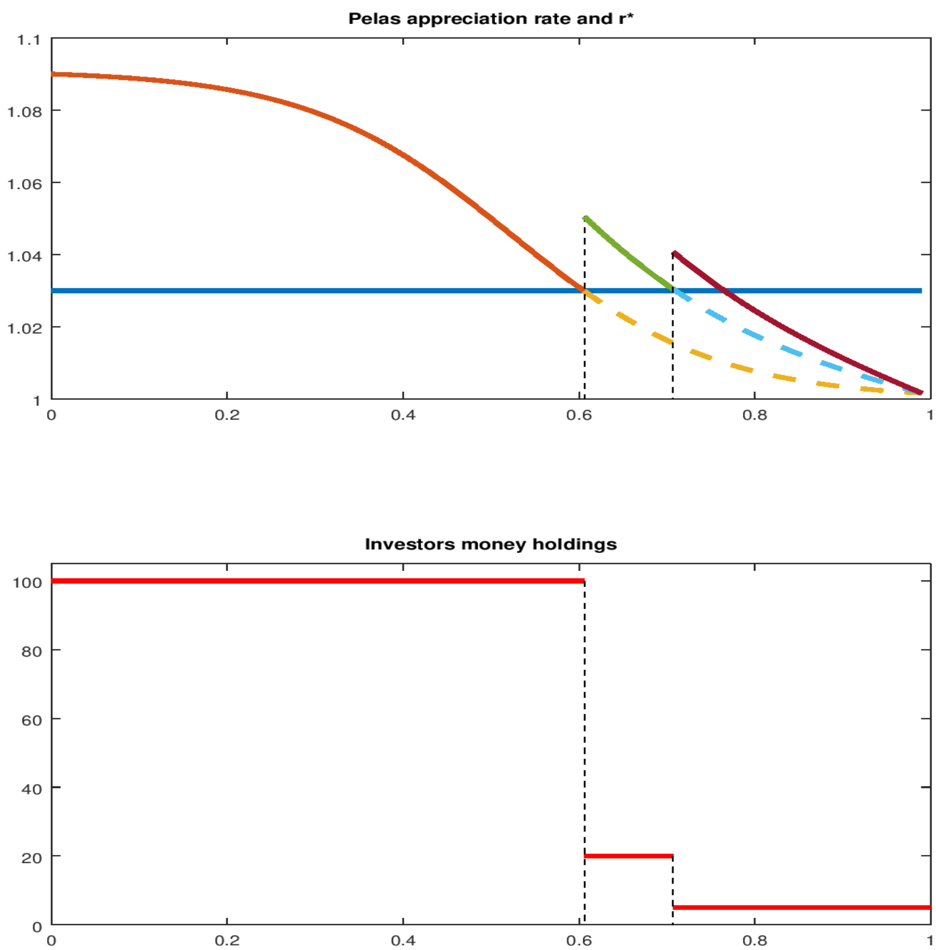


Figure 7: Investor's money holdings in the adoption period

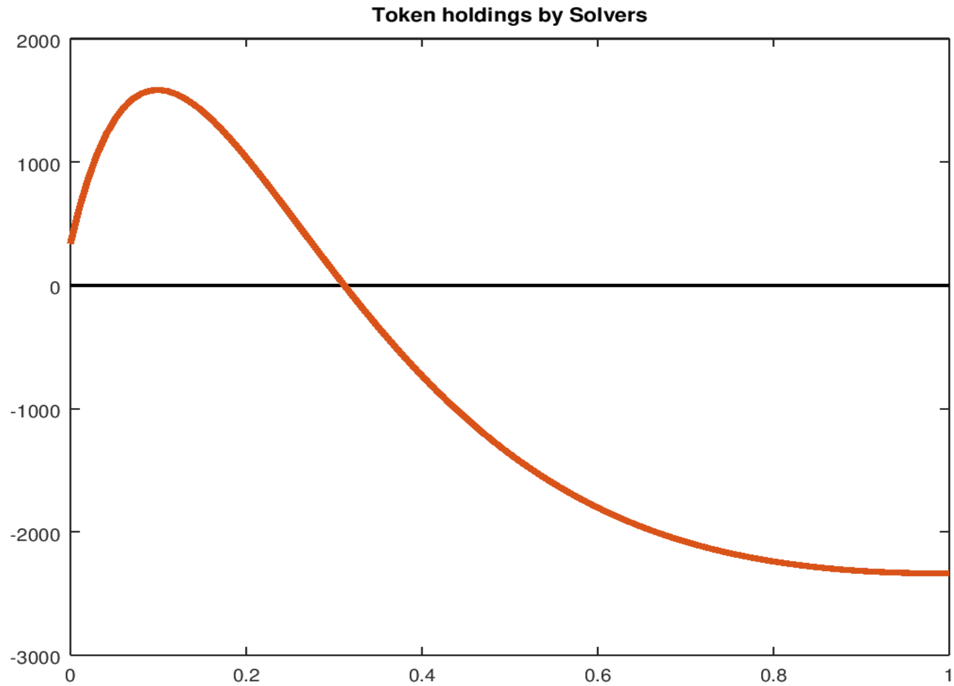


Figure 8: A failed ICO with a death spiral

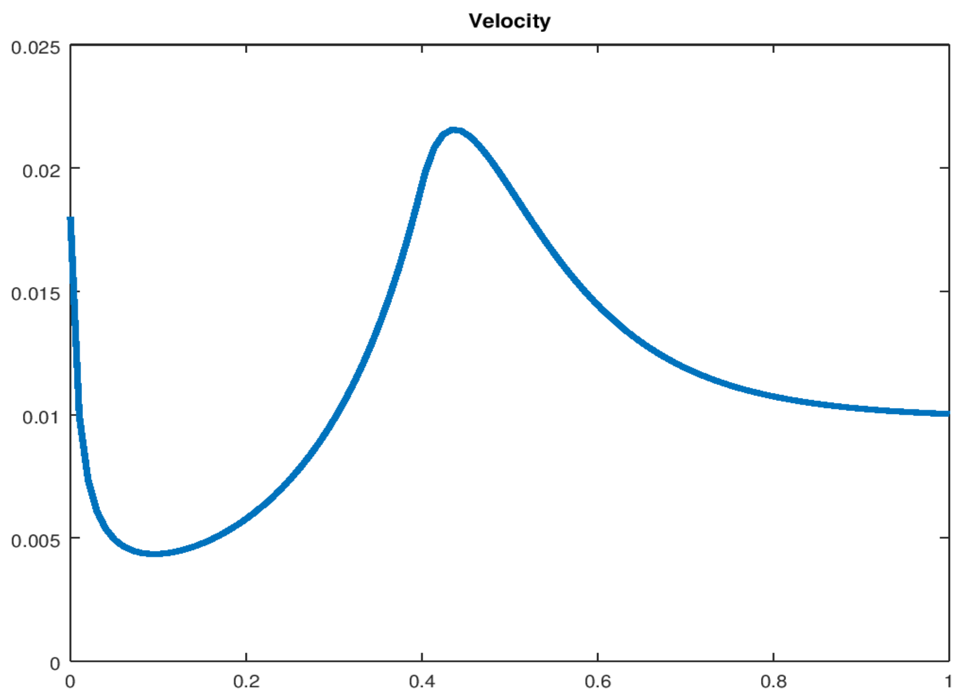


Figure 9: Velocity as $V_t = \frac{q_t y_t}{m_t}$

a different pattern for velocity, and velocity would have been explained by a different behaviour of those agents.

4.3 Extensions

We have indulged ourselves into a carefully tailored example to provide, not solely numerical solutions (as it is the usual case) but also analytical solutions. The goal is to easily connect each aspect of the model with the structure of the solution. As the example has been tailored with losses of generality, some clarifying words are in order.

First, the solution does not contain, (and therefore does not depend) on the parameter values of η, μ and σ. Two assumptions have been put into play in order to achieve the simplest possible analytical solution. The first one is that the solver has idle resources. Think of a car driver that act as a solver in the ride economy. Imagine that this driver is *already* driving for a standard firm, and time to time the driver uses her own resources to sell them to the platform. Then, her income will have two parts, one $w_t l_t$ that is the hours worked in the platform and expressed in $\wp$, but it would also earn $w_t^e(L - l_t)$ which is the wage in fiat times the remaining time from total endowment L. If we further assume that there is perfect arbitrage between activities, then total income is always the wage (in fiat or crypto) times total time L. This trick allow us to detach personal income of the solver from the evolution of the business plan. That is the reason why only T plays a role in the determination of M_0. A more general model would incorporate into wages the efficiency gains obtained from the platform, making solver's income dependent on adoption. In that case, the parameters of adoption will enter in the solution and will help to determine m_T.

Likewise, investors are assumed to follow the recommendations of Sideblock foundation simply because they are assumed to be very small. Of course they can only be small if a large number of investors buy very small shares of the monetary base at the ICO. If this is not the case, a large investor, or market makers (see Keidar and Daniels, 2018) could profit from the scheduled time series for q_t anticipating the demand for money generated for transactions motives. If investors optimize over the scheduled demand of solvers, the latter would have to modify its demands, that will in turn, produce a reaction on the investors and so on, inducing possibly non-convergent dynamics that could lead to death prices (see Sarin, 2018).

Secondly, it is also possible to introduce uncertainty and let the agents make a guess on the evolution of the business plan based on observed values along the adoption path, letting them to adjust their net money demand to their expectations on the future realizations of adoption. We have ruled out this possibility by solving the model with agents endowed with perfect foresight.

Thirdly, the proposed revaluation scheme follows an auto-regressive process where the next value is entirely determined by the previous one. Assuming linearity in the evolution of exchange rates, generates a nice yield curve, while keeping the analytical solution feasible. Indeed, other pricing processes can be postulated, while this one makes very easy to introduce noise in the determination of exchange rates. How sensitive is money supply to shocks or to different specifications is of course of great interest.

Finally, we have also assumed that this two sided economy is somehow only connected to the rest of the world by some fiat money that stays stable. To generate a crypto ecosystem is feasible from this benchmark. Each solver can be at the same time a troubler in a different market having different preferences and discount rates, making agents to hold a crypto portfolio where, maybe, Bitcoin is the reference currency. Such an environment would be helpful to illustrate the kind of co-integrated fluctuations that we observe in cryptoland. But maybe not, and we can explore the predictions of models where the cryptoworld is shocked by fluctuations in the fiat world.

5 Concluding remarks

The paper has shown a remarkable property of two-sided markets that are articulated through a Dapp: the asymmetric information problem, and most of the frictions that characterize a market with lots of heterogeneous participants are smoothed out, creating a market where an homogeneous good or service (or more generally, a problem) can be traded without those frictions. Because of that, we can recover the market solution using the standard tools that characterize the Arrow-Bedreu economy with the competitive equilibrium as a solution concept.

Since welfare theorems apply in our setting, it is possible to postulate a sequence of prices (exchange rates) for q_t, and solve the Solver's problem to compute the demand for tokens that would be observed under that price scheme. Once we know the demand, we only have to match it with the supply of tokens to support the prices that generated that demand, with all incentives aligned. We have therefore shown that regular demands an supplies emerge from the interaction of heterogeneous agents through the Dapp, and as a consequence we can resort to standard existence theorems.

Nevertheless, to encompass in our framework the double emission of a utility token together with a security token is not problematic at all. However, a securitization of the platform has implications on decentralization of production. We do not enter here in the normative discussion, but we simply notice that the problem is already written in a way that makes it very easy to study the interactions between a simultaneous ICO and a STO.

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