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Monetary holdings, speculation, and transaction costs stability in two-token blockchains*

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Nicola Dimitri

Monetary holdings, speculation and transaction costs stability in two-token blockchains*

Abstract

Dual-token models are being adopted by blockchains more and more frequently, towards an effort for improving stability and functionality of the platform. Despite their increasing importance and complexity, contributions for a deeper understanding of their underlying features seem to be lacking. In an attempt to try filling this gap, this study investigates the economic ramifications of this model, focusing on three main related issues. The dynamics of the two-token holdings, and how they relate to each other. The multiplier effect and dual pricing's potential, for speculative trading, which may emerge when one token can be obtained for free by holding the other token. The possible difficulty in preserving stable transaction costs, in fiat currency, which represents a main goal in some blockchains. The author proposed a theoretical framework to examine these three points and talk about how they affect users and blockchain platforms. Based on this research, dual-token blockchains appear to have some advantages but also bring additional economic complexity that needs to be carefully managed.

1. Introduction

Since the advent of Bitcoin (Nakamoto, 2008), blockchain-based electronic platforms have typically issued a *native token*, cryptocurrency, introduced to perform a variety of operations within the platforms. How to issue, and manage, tokens originated the whole new area of tokenomics (Cong et al, 2021; Freni et al., 2022; Lo-Medda, 2023; Shen et al, 2023; Kiayias et al, 2024)

Most frequently such *native tokens* are used for financial transactions. That is to transfer money between two accounts of the relevant network or, for example, to pay for computational costs when implementing functions such as smart contracts (SC). However, they are also used for other purposes such as, for instance, to obtain voting rights in governance decision making sessions. This is why the token market price, normally expressed in terms of a fiat currency, or other cryptocurrencies, takes on a particularly important function. Such price is determined within exchange nodes and automated market makers, where the token is traded against fiat currencies as well as with cryptocurrencies. The price emerges from the interplay between the market demand and supply of the token, versus the other currencies, and it is an expression of the degree of interest in the token, hence in the platform.

Therefore, a token price can be considered a very informative economic indicator of the platform attractiveness. However, for a platform adopting a single token, its market price in fiat currency, being unique, cannot transmit precise information on the relative desirability of the various functions performed by the token on the platform. Yet, such functions are likely to be related and if the platform, for example, enjoys a good reputation in the market for implementing smart contracts, it may also be attractive for users to participate in its governance.

Nonetheless, this is not necessarily the case and, moreover, paying transaction costs with the native token can make the fees volatile in terms of their corresponding fiat currency value. For this reason, as an attempt to stabilize transaction fees expressed in fiat currency, as well as to improve the precision of the functions performed by a token, in recent years some blockchain platforms began to introduce two or more tokens, each performing different tasks. In particular, Mayer (2022), observes that price stabilization of the second token could be fully accomplished in case it is a stablecoin, that is with a one-to-one exchange rate with respect to a fiat currency. Then if such tokens can be traded against other currencies, and become available in exchange nodes, their economic price could inform users more precisely on the degree of attractiveness of the different functions available in the platform. For completeness, it is worth observing that not every second token has been introduced for transaction fees stabilization. In particular security, in blockchains adopted by local communities, has also been a reason for that (Domenicale et al, 2024).

Inspired by the VeChain platform (VeChain Foundation, 2019), a two-token blockchain founded in 2015, based on a Proof-of-Authority consensus protocol, in this paper we analyse dual-token blockchains from an economic perspective. However, the findings that we obtain can have a broader validity, with appropriate adjustments, also in other two-token platforms. Indeed, for example, SORA (Takemyia, 2019) and NEO (2023), are blockchains where the two tokens play a slightly different role than in VeChain although, on the overall, their structure and relevant economic issues exhibit similarities Dimitri (2023). There are also platforms with even three tokens like Steem (Steem, 2018), however with characteristics which differ as compared to those investigated in the paper. Indeed, as for Steem only two of the tokens are tradable, while the third is not. Moreover, one of the tradable tokens is a stablecoin which, unlike the two-token platforms that I consider, by definition is not volatile. Despite its recent diffusion, (Hardin-Kotz, 2021; Manolache et al, 2022; Alexandrescu et al., 2025; Calandra et al.,2025; Chackraborty et al.,2025) until very recently (Kiayias et al, 2024), there did not seem to be extensive economic analysis of dual-tokens economies although, at a high level, they are more complex than single token platforms and require proper understanding. This is what motivated our paper. Indeed, besides specifying the tokens' functions the blockchain needs to clearly state the rules for issuing them, in what quantity and when, if and how both tokens are tradable etc.

In particular, the paper has three main goals, which are discussed in the three principal sections of the work. However, our work differs from the only two theoretical contributions that we are aware of by Dimitri (2023) and Kiayias et al. (2024). The former proposes alternative ways to define the economic value of two-token platforms based on market prices and traded volumes of currencies. The latter focuses on a game theoretic analysis to discuss desirability of long-run equilibria in two-token blockchains.

In the initial part we discuss a foundational issue, that is a representation of the users' tokens holdings evolution of the system. This is done by defining a two-equation dynamical system, where the dynamics is specified by the number of blocks in the chain. The two equations will refer to the two tokens and, by the rules of the platform, will be interdependent. Whether or not tokens can be traded on the market clearly conditions the evolution of the system.

The second part of the paper will identify a feature, which is intrinsic to two-token blockchains, when both tokens are traded in the market and one of them could be obtained for free, as a bonus, by holding/staking in one's wallet the other token. Such specific feature is the possibility of speculation activity, taking place by exchanging the two tokens several times, to exploit what we called the *dual price* phenomenon and/or the *multiplier effect* phenomenon. The two phenomena hinge on the same logic, that is on the fact that one of the two tokens can be obtained for free by owning the other token.

In the third part of the work, we investigate the conditions for transaction costs stability in fiat currency. Based on our notions of stability, our findings suggest that stability requires a specific relation between the *gas* price, paid in units of a token, and the token market price in terms of a fiat currency. Gas is a virtual unit of account needed to implement transactions, originally introduced by Ethereum

(Buterin, 2014). Every operation on the blockchain needs a certain number of gas units, which is paid in one of the two tokens. Each user proposes her own gas price, that is how many units of the token she's willing to pay for one unit of gas; the larger the proposed price the sooner a transaction would be included in a block. The condition for transaction costs stability that we obtain is very specific, and not always easy to achieve by the platform, since it depends on several quantities, many of which the blockchain cannot control directly. The reason why transaction costs stability is an issue, also with two tokens, it is because even if the number of gas units for an operation on the blockchain remains the same across different blocks, the token with which gas is paid is traded on the market and also subject to price volatility in terms of a fiat currency, unless it is a stablecoin.

The paper is structured as follows. In Section 2 we introduce the model fundamentals and present the two-equations dynamical system describing the evolution of the users' token holdings. Section 3 is dedicated to discussing the issue of potential speculative trades, intrinsic to blockchains where both tokens are traded on the market and one of them is obtained for free by holding the other token. In Section 4 we investigate the transaction costs stability issue in fiat currency, while Section 5 concludes the paper.

2. The dynamics of tokens' holdings

In this Section we set up some fundamentals of dual token economies. To make the description more realistic we shall refer to VeChain as an example to describe *two tokens* blockchains. Yet, our findings will in general be valid also for other dual token blockchains, such as NEO (2023), which however exhibits some differences in the generation of the second token, that for completeness we discuss below.

VeChain is characterized by two tokens, and in what follows we shall use its notation, as it appears in the White Paper. The first one is called VET, that we shall indicate with V, while the second is called VTHO, that we indicate with E; the two tokens coexist in the system, performing different functions. To simplify the terminology in the paper we shall typically refer to V and E to mean the type of tokens. The V tokens, which provide voting rights (VeChain Foundation, 2019) in the blockchain governance decision making, are used for, possibly, sophisticated business exchanges while E are needed to pay for smart contracts and transaction fees on the platform. Hence, the two tokens allow users to perform different functions, and their desirability may be expressed by the associated market prices, when both of them are traded in exchange nodes. In principle, their market prices can be independent of each other but, in fact, since they refer to the same platform they are expected to be related. As a matter of fact, the market prices of V and E in reality appear to exhibit a slightly negative correlation. This is the simple intuition. When demand for V is high its market price increases and, at the same time, the generation of E tokens increases which reduces its market price, and the opposite.

An important institutional feature of Vechain, as well as of other dual token platforms, is the following. Tokens E are generated from V with no out-of-pocket expenditure, conditional to V holders participating in the blockchain governance activities. Additionally, both V and E are traded in exchange nodes on, what we shall call *external* market. By this we intend exchange nodes such as Binance, and others, which are willing to trade the two tokens. On the generation

As an example, considering as reference CoinMarkeCap, on $26\ July\ 2022$ the V price expressed in \$, which at generic time t we indicate by $p_{V\$}(t)$, with units of measurement $\frac{\$}{V}$, was $p_{V\$}(t) = 0.023$ while the E price was $p_{E\$}(t) = 0.0019$, expressed in terms of $\frac{\$}{E}$, which implied that $\frac{p_{V\$}(t)}{p_{E\$}(t)} = 12.10$. On $26\ July\ 2023$ it was $p_{V\$}(t) = 0.019$ and $p_{E\$}(t) = 0.0011$ with $\frac{p_{V\$}(t)}{p_{E\$}(t)} = 17.27$.

Based on these two observations it follows that both tokens, with respect to the previous year, lost some degree of desirability in the market but that token V has become relatively more attractive than token E. Namely, the blockchain might have generated over the relevant year more interest for governance participation than for implementing transactions and smart contracts. More recently, on 28 September 2025, it was $p_{V\$}(t) = 0.018\ and\ \ p_{V\$}(t) = 0.0013$ and $\frac{p_{V\$}(t)}{p_{E\$}(t)} = 13.85$ became lower again. However, since market prices neither consider the absolute value of traded quantities, nor the traded quantities with respect to the circulating units of a token, the above observation, based on prices only, should be taken with some care.

While V tokens, assuming their total supply is already introduced in the platform, can only be purchased on exchange nodes, to obtain E tokens there is a double channel: the inside generation of E from ownership of V and the exchange nodes. To better appreciate the implications of such double channel for E, we proceed gradually in the analysis considering initially only one channel available: ownership of V token but no possibility to trade E in any market.

That is, we assume that smart contracts and transaction activities are only allowed for users holding the native V. Therefore, ownership of E requires ownership of V.

Later we shall introduce the possibility to exchange E tokens, within the VeChain platform as well as in the external market, that is other exchange nodes. Indeed, although currently, E could only be obtained in the external markets, namely in such exchange nodes, for the sake of completeness in the paper we also consider the possibility of an internal market, within the VeChain platform or related wallets.

It is interesting to anticipate that, as we shall see, even if V tokens can be purchased against a fiat currency in exchange nodes, while E tokens can be exchanged only in the internal market against V, this can originate what we call a *dual price* of E in terms of a fiat currency which may, in principle,

generate speculative trades. However, details on this are deferred until Section 3, since below we first need to introduce the economic fundamentals of the platform.

To this Paragraph, for comparison it may be interesting to mention that in NEO the main token is called NEO while the other token is called GAS. The latter is used to pay for blockchain operations and, at every block, 5 units of GAS are minted and distributed, in different percentages, to NEO holders, voters and NEO Council Members. This means that the generation process of GAS tokens is slightly different from the one of E tokens, though not to the extent that our findings could not be, at least partly, translated to NEO.

In the next paragraph we start from the benchmark case, in which E can be traded in no market.

2.1 Token holdings dynamics with no exchange of E tokens

In this paragraph we begin setting the framework fundamentals. To start with, we do not allow E to be traded in any market, whether internal or external. Therefore, E could only be saved or used for transactions. Instead, tokens V could be exchanged in an external market, the implications of which however will be discussed later.

Suppose N_b is the number, as well as the set, of users in the blockchain, after validation of the generic block b, and before validation of block $(b+1)$, with $b = 0,1,\ldots$ being the generic block and $i = 1,..,N_b$ the generic user in the blockchain. To avoid repetitions henceforth, when referring to block b, we shall always mean after its validation and before block $(b+1)$ validation. For simplicity we shall also assume that one user corresponds to one node, and due to this in the paper we will refer to them interchangeably.

Moreover, define $h_{Vi}(b)$ and $h_{Ei}(b)$ as, respectively, the number of tokens V and E, held by user i, at block b. It may well be that across few blocks the token holdings of several users would not change. However, to have a sufficiently flexible, and general, model we keep the block index as a main reference in the analysis.

It follows that

$$h_V(b) = \sum_{i=1}^{N_b} h_{Vi}(b) \quad and\ h_E(b) = \sum_{i=1}^{N_b} h_{Ei}(b)$$

represent the total holdings, quantity-supply, in the system of, respectively, V and E at block b. Finally, we define $g_{Ei}(b)$ to be user i's expenditure, in E tokens at block b, for gas usage.

Throughout we assume $h_{Ei}(b), g_{Ei}(b) \geq 0$. What follows represents the fundamental *dynamic* equation relating $h_{Ei}(b)$ and $h_{Vi}(b)$, with the dynamics being defined by the number of validated blocks

$$h_{Ei}(b) = \begin{cases} h_{Ei}(b-1) + h_{Vi}(b)v_b - g_{Ei}(b) & with\ b = 1,2,\dots \\ h_{Vi}(b)v_b - g_{Ei}(b) & with\ b = 0 \end{cases} \quad (1)$$

where $v_b > 0$ is the so-called *velocity* coefficient, fixed by the platform, linking the holdings of E to the holdings of V . In words, except for block $b = 0$, equation (1) specifies that $E's$ holdings at block $b > 0$ are given by the holdings at the previous block, plus the number of E generated by V minus those units spent for gas. That is, at $b = 0$ no holdings of E are inherited by the user from a previous block, that does not exist.

Likewise, the equation describing the *dynamics* of $h_{Vi}(b) \geq 0$ is given by

$$h_{Vi}(b) = \begin{cases} h_{Vi}(b-1) + f_{Vi}(b) & with\ b = 1,2,\dots \\ h_{Vi}(b) & with\ b = 0 \end{cases} \quad (2)$$

where $f_{Vi}(b)$ is the difference between the number of V tokens received and the number of V tokens spent, by user i, between block $(b-1)$ and block b. From $h_{Vi}(b) \geq 0$ it follows that $h_{Vi}(b-1) \geq -f_{Vi}(b)$ represents a feasibility constraint for token holdings.

The pair of equations, (1) and (2), provide a complete definition of the system dynamics in terms of a users' monetary holdings. However they are identities, hence necessarily satisfied, and do not explain how the relevant quantities are determined, which clearly depends upon users' preferences. Therefore, based on the above considerations, empirical validation of the above equations is not an issue.

However, before introducing utility functions, it is worth pointing out in details how (1) and (2) work. To see how (1) works start considering $b = 0$, that is

$$h_{Ei}(0) = h_{Vi}(0)v_0 - g_{Ei}(0) \quad (3)$$

It is immediate to see that to define the quantities in (3) user i has to take two decisions: first choose $h_{Vi}(0)$ and then $h_{Ei}(0)$, or $g_{Ei}(0)$. Indeed, once $h_{Vi}(0)$ is selected the number of E available to i, that is $h_{Vi}(0)v_0$, will be automatically determined by the platform, which then the user has to decide how to distribute between $h_{Ei}(0)$ and $g_{Ei}(0)$.

Therefore, at $b = 0$, the available number of E tokens for a generic user is completely determined by V tokens and given by $h_{Vi}(0)v_0$. For this reason, the holdings of V have a double effect. On the one hand they produce *direct* benefits in financial exchanges, governance etc., while on the other hand they also provide *indirect* benefits by generating E tokens. Of course, the allocation of E tokens by a user will depend on the requested gas, to pay for transactions and smart contracts to insert in block $b = 0$ as well as, possibly, upon how much gas will be needed in future blocks to execute those functions. As said, to further investigate this point, we shall need to introduce the user's preferences, that is her utility function, a discussion which however we postpone until later.

Consider now (1) with $b = 1$; then

$$h_{Ei}(1) = h_{Ei}(0) + h_{Vi}(1)v_1 - g_{Ei}(1) \quad (4)$$

As well as for (3), to determine $h_{Ei}(1)$ user i will have to choose two quantities. Indeed, while $h_{Ei}(0)$ obtains from (3), $h_{Vi}(1)$ and $g_{Ei}(1)$ have to be selected at block $b = 1$. In analogy with expression (1), once $h_{Vi}(1)$ is chosen the level of $g_{Ei}(1)$ is determined through user $i's$ preferences.

This means that user $i's$ total number of E tokens available at $b = 1$ is given by $h_{Ei}(0) + h_{Vi}(1)v_1$, that is by the E holdings inherited from block $b = 0$ plus the newly generated ones $h_{Vi}(1)v_1$, minus the gas expenditure $g_{Ei}(1)$.

Replacing (3) into (4) we obtain

$$h_{Ei}(1) = h_{Vi}(0)v_0 + h_{Vi}(1)v_1 - g_{Ei}(1) - g_{Ei}(0) \quad (5)$$

which can be generalised to any $b > 0$ as follows

$$h_{Ei}(b) = \sum_{k=0}^{b} (h_{Vi}(k)v_k - g_{Ei}(k)) \quad (6)$$

and, analogously, the number of E tokens available to user i at generic block $b > 0$ is $h_{Ei}(b-1) + h_{Vi}(b)v_b$. Therefore, to determine $h_{Ei}(b)$ user i needs to select $2(b+1)$ quantities.

As a benchmark example, suppose $h_{Vi}(b) = h_{Vi}$, $v_b = v$ and $g_{Ei}(b) = g_{Ei}$ for all $b = 0,1,2 \ldots$, that is all the relevant quantities are constant across the blocks. Then it follows that

$$h_{Ei}(b) = (b+1)(h_{Vi}v - g_{Ei}) \quad (7)$$

namely that $h_{Ei}(b)$ increases linearly with b, with the line slope being given by $(h_{Vi}v - g_{Ei}) \geq 0$.

If $(h_{Vi}v - g_{Ei}) > 0$ then, at each block, the user will have a surplus of E tokens with respect to the units needed to purchase gas. If users are not interested in saving E tokens for future usage, such excess of tokens can be seen as a *social loss, waste*, since users neither need them nor they can exchange them against assets or other currencies.

Instead, if $(h_{Vi}v - g_{Ei}) = 0$ the user will have no holdings of E tokens, since at each block the E tokens will all be used to pay for gas consumption.

Definition (1) immediately extends to the whole community of users as

$$h_E(b) = \begin{cases} h_E(b-1) + h_V(b)v_b - g_E(b) & with\ b = 1,2,\ldots \\ h_V(b)v_b - g_E(b) & with\ b = 0 \end{cases} \quad (8)$$

where $g_E(b) = \sum_{i=1}^{N_b} g_{Ei}(b)$. The case of $h_E(b) = 0$ represents a complete allocation of E in the community for gas consumption while $h_E(b) > 0$ stands for an overall surplus of E, which may be due to an unbalance between the needs to implement transactions, smart contracts (SC), and the generation of E tokens from V tokens.

2.2 Demand for E tokens

In Section (2.1) we analysed the dynamics of E holdings, however without discussing how users choose them. We now enter into some more details on the allocation of E tokens for a generic user, to discuss how the available quantity is distributed between gas expenditure and holdings for future usage.

To simplify the exposition, without major loss of generality, we assume that between validation of blocks b and $(b+1)$ users implement at most one operation, either a transaction or a smart contract. In this case, user $i's$ needed gas G_{bi} will satisfy $G_{bi} > 0$. When no operation is executed, it is $G_{bi} = 0$. Since we do not allow to exchange E tokens, the only reason for demanding $h_{Ei}(b) > 0$ is that i may want to have a stock of tokens now, for example in view of a decrease in the future stock of V, which in turn would decrease the future number of generated E units.

We indicate as $D_{Ei}(b)$ user $i's$ total demand of E tokens for executing functions on the blockchain, upon validation of block b and before validation of block $(b+1)$. This will be given by

$$D_{Ei}(b) = p_{bi}G_{bi} + h_{Ei}(b) = h_{Ei}(b-1) + h_{Vi}(b)v_b \qquad (9)$$

where $G_{bi} \geq 0$ is the number of gas units requested by i to execute SC and transactions, while p_{bi} is the unit price of the gas, expressed in $\frac{E}{Gas}$, proposed by i for gas units. The higher the submitted gas price, the larger the transaction fees paid to block validators, the sooner the transaction will be included in the blockchain.

Building on previous discussion, and assuming desirability of E, from (9) it is clear that the *overall demand of E tokens* at block b is, in fact, *already* determined by the quantity of V at block b and by the E token holdings at block $(b-1)$. In a sense, the demand of E perfectly adjusts to the supply of E. So, once $h_{Vi}(b)$ is determined the user needs only to decide how to *allocate* the E tokens between $p_{bi}G_{bi} = g_{Ei}(b)$ and $h_{Ei}(b)$.

To be precise, the equality in (9) should have been written as a weak inequality $\leq$, to express that demand cannot exceed supply, that is demand feasibility. However, assuming that E tokens are desirable, that is an agent's utility increases with the holdings of E, then the formulation of (9) is justified.

This choice depends on G_{bi}, p_{bi} and on the need of E tokens for future transactions. In principle, for any G_{bi} the optimal price for the user would be $p_{bi} = 0$ which, obviously, would make the platform unfeasible, should most users propose that. In any case, a too low a price would delay, possibly even for a long period, the inclusion in a block of the user's transactions/SC.

Although we shall discuss this later in more details, it may be interesting to anticipate how the choice of $g_{Ei}(b)$ can originate. A simplest way to see this is by introducing the following linear utility function, that is user $i's$ preferences, at each generic block $b = 0,1,2$ .....

$$U_i\big(g_{Ei}(b); h_{Ei}(b)\big) = g_{Ei}(b) + \delta h_{Ei}(b) \qquad (10)$$

where $0 \leq \delta \leq 1$ is the discount factor of user i and $\delta h_{Ei}(b)$ the present value, at block b, of the holdings $h_{Ei}(b)$ available at block $(b+1)$. As is well known, (10) is also expressing the utility function of a *risk neutral* user, in the two arguments $g_{Ei}(b)$ and $h_{Ei}(b)$. This also amounts to say that $g_{Ei}(b)$ and $h_{Ei}(b)$ are *perfect substitutes* for user i, with the substitution rate being ruled by δ. Since risk neutrality may not be the prevailing risk attitude, below we shall discuss how a user's choice would change with risk aversion.

The utility function in (10) is capturing the idea that while $g_{Ei}(b)$ provides immediate benefits, at block b, the benefits originated by $h_{Ei}(b)$ refer to the next block $(b+1)$. Assuming $h_{vi}(b)$ as already been chosen by user i, and that $h_{Ei}(b-1)$ is inherited from the previous block, she would have to solve the following constrained maximization problem

$$Max_{g_{Ei}(b),h_{Ei}(b)} U_i\big(g_{Ei}(b); h_{Ei}(b)\big) \quad such\ that\ g_{Ei}(b) + h_{Ei}(b) = h_{vi}(b)v_{bi} + h_{Ei}(b-1) \quad (11)$$

which can be re-written as

$$Max_{g_{Ei}(b)} U_i\big(g_{Ei}(b)\big) = g_{Ei}(b) + \delta\big(h_{vi}(b)v_{bi} + h_{Ei}(b-1) - g_{Ei}(b)\big) \quad (12)$$

It is immediate to find the solution, of problem (12), as being given by

$$g_{Ei}(b) = \begin{cases} h_{vi}(b)v_{bi} + h_{Ei}(b-1) & if\ \delta < 1 \\ [0, h_{vi}(b)v_{bi} + h_{Ei}(b-1)] & if\ \delta = 1 \end{cases} \quad (13)$$

That is, with a linear utility function (as in (12)), a *risk neutral* user, the more likely decision (that is when $\delta < 1$) is that all the E tokens would be used to buy gas. This implies that since $g_{Ei}(b) = p_{bi}G_{bi}$, then the user will submit a unit price given by

$$p_{bi} = \frac{[h_{vi}(b)v_{bi} + h_{Ei}(b-1)]}{G_{bi}} \quad (14)$$

which is the maximum price that she could offer, given the available number of E tokens.

Though simple, the above example suggests that the utility function, that is the user's preferences, plays a crucial role in determining the allocation of E between gas and token holdings. Indeed, consider now a *risk averse* user, in both $g_{Ei}(b)$ and $h_{Ei}(b)$, so that (10) becomes

$$Max_{g_{Ei}(b)} U_i\big(g_{Ei}(b)\big) = W(g_{Ei}(b)) + \delta W\big(h_{vi}(b)v_{bi} + h_{Ei}(b-1) - g_{Ei}(b)\big) \quad (15)$$

where W is a twice differentiable function such that $W' > 0$ and $W'' < 0$, hence concave in the argument. Then, because of concavity, the first order condition associated to (15)

$$\frac{W'(g_{Ei}(b))}{W'(h_{Ei}(b))} = \delta \qquad (16)$$

provides a solution to (15). From (16) it follows that $g_{Ei}(b)$ increases as δ decreases and viceversa. More specifically, if $\delta = 1$ then $g_{Ei}(b) = \frac{(h_{vi}(b)v_{bi} + h_{Ei}(b-1))}{2} = h_{Ei}(b)$ while for $\delta < 1$ it is $g_{Ei}(b) > h_{Ei}(b)$.

As an illustration of (16), for the case of $W(x) = \log(x)$ and $\delta < 1$, we obtain

$$g_{Ei}(b) = \frac{(h_{vi}(b)v_{bi} + h_{Ei}(b-1))}{(1+\delta)};\ h_{Ei}(b) = \frac{\delta(h_{vi}(b)v_{bi} + h_{Ei}(b-1))}{(1+\delta)} = \delta g_{Ei}(b) \quad (17)$$

and, therefore, the proposed price is

$$p_{bi} = \frac{[h_{vi}(b)v_{bi} + h_{Ei}(b-1)]}{(1+\delta)G_{bi}} = \frac{g_{Ei}(b)}{G_{bi}} \quad (18)$$

Hence, the more patient is the user, namely as δ increases, the smaller is $g_{Ei}(b)$ and the opposite. In any case, the gas expenditure will never be lower than half the number of available E tokens.

It is worth observing that, in both (14) and in (18), the unit price submitted is inversely related to the requested gas G_{bi}. As a consequence, if the user is willing to augment the chance of including her transaction/SC in the next block she could either increase the submitted price by reducing $h_{Ei}(b)$ and/or by decreasing the request of G_{bi}, if this is feasible. Indeed, once the user has decided which transactions/SC to implement, the needed amount of gas G_{bi} is fixed by the platform. So, the agent can only decide which operations to execute but not how much gas such operations will need.

From (9) the total demand for E tokens made by all users after block b validation is

$$D_E(b) = \sum_{i=1}^{N_b} D_{Ei}(b) = \sum_{i=1}^{N_b} (p_{bi}G_{bi} + h_{Ei}(b)) = p_b G_b + h_E(b) \quad (19)$$

where $G_b = \sum_{i=1}^{N_b} G_{bi}$ is the total gas requested by users between blocks b and $(b+1)$ and $p_b = \sum_{i=1}^{N_b} p_{bi}(\frac{G_{bi}}{G_b})$ is the average price, across users, weighted by the share of G_b that each of them requested.

In definition (19), keeping the rest as given, the larger is p_{bi} the higher is p_b and, in general, the more users are competing with each other to include their SC and transactions in the next block, or as

soon as possible. Observe that the level of p_{bi} and G_{bi} may depend upon several elements, some of which we discuss in the sequel.

Finally, it is important to point out that users, in reality, may neither be perfectly informed nor maximise their utilities, but rather choose according to other criteria. Indeed, there is a growing behavioural literature Ballis-Verousis (2022), Yousef-Yarovaya (2022) showing how users' choice on in digital finance may be explained by herding behavior Dedousi-Fassas (2022), James-Menzies (2025), that is by imitation.

2.3 Token holdings dynamics with exchangeable E tokens

Based on previous considerations we can start discussing the *market* for E tokens. Since we have not yet introduced the possibility to trade E tokens a very first, primitive, notion of *market* that we can consider is simply the joint analysis of tokens supply, as specified by (1) and token demand, for executing transactions and smart contracts, defined by (9).

In our discussion we assumed that for each user demand is equal to supply and, therefore, that the entire market is always in equilibrium. That is, the individual number of E tokens represent a constraint for the user who, we assume, considers as desirable to take the largest possible quantity, either for gas or for future operations, in her wallet. However, it is interesting to mention that in principle there could be reasons, for a user, to demand a number of E tokens which is lower than her available number when, for example, there would be opportunity costs for keeping tokens in the wallet.

If instead, at the submitted price, a user would wish to have a number of E tokens larger than the available one, then her demand would be rationed, that is partly unsatisfied. Of course, for a given supply, however large G_{bi} may be, there always exists a low enough price level p_{bi} such that demand equal to supply. However, such price may be undesirable for the user in the sense that, for example, the inclusion of the transaction/SC in the block may be heavily delayed if the price is low.

2.4 Exchanging E tokens in an internal market

Until now we assumed that E tokens can only be used to execute transactions/SC on the platform or saved in one's wallet. In this section we introduce the possibility to exchange E with other currencies/tokens. As anticipated, the main reason for introducing the market is very simple. Indeed, some users may need less/more E units than they can generate with the available V, and so they can enhance their utility, welfare, by being able to trade both tokens. To gain initial insights on the implications of exchange activities, below we begin considering an *internal* market for E only, to which we shall later add an *external* market. By *internal* we mean a market operating within the platform, or

an associated wallet, where E can *only* be traded against V, and the opposite. By *externa*l we refer to the standard markets, operated by exchange nodes *outside the platform* community.

Notice that, in reality, the only operating market for E is typically the external one, where a a number of exchange nodes may be willing to trade the tokens. However, to earn additional insights on the effects of trading both V and E, below we shall consider the two types of markets. Therefore, at this stage V could be purchased in two main ways. First, in standard external exchange nodes, against fiat currencies or crypto currencies or, alternatively, in the internal exchange market against E which, instead, can only be purchased in the internal market. For this reason, the intuition suggests that the internal market price of V, in terms of E, is likely to be related to the external market price of V in terms of fiat/crypto currencies, as well as to the rate v with which V generates E, in the platform.

In order to discuss the implications of the *internal* exchange market, define $\in_{Ei}(b)$ to be the amount of E tokens exchanged by user i against V tokens at block b. Likewise, the quantity $q_b \in_{Vi}(b)$ represents the number of E tokens obtained by exchanging the amount $\in_{Vi}(b)$ of V at the unitary exchange rate q_b. Indeed, q_b defines the number of E which can be obtained with a single V token at block b, expressed in terms of $\frac{E}{V}$.

To start gaining insights on the implications of an internal market, consider block $b = 0$ and suppose that user i can make, at most, one transaction between the validation of two consecutive blocks. She can either sell E to buy V, alternatively she can sell V to buy E, or none of them. Finally, to simplify the exposition, assume also that V tokens are all introduced initially into the platform. Based on such assumptions then

$$h_{Ei}(0) = h_{Vi}(0)v_0 - g_{Ei}(0) - (\in_{Ei}(0) - q_0 \in_{Vi}(0)) \qquad (20)$$

are user $i's$ holdings after the initial block $b = 0$. The formulation of (20) is due to the following, additional, assumptions concerning the timing of operations, after validation of block $b = 0$ and before validation of block $b = 1$. User i holds $h_{Vi}(0)$ which first generates $h_{Vi}(0)v_o$ units of E. Then user i decides $g_{Ei}(0)$, $\in_{Ei}(0)$, $\in_{Vi}(0)$ hence $h_{Ei}(0)$. The price, rate, q_0 is given by the market equilibrium condition, between demand and supply. That is, as a first approximation, we assume q_b to be independent from an individual's supply-demand, so that it is a given for the users.

Notice that an alternative formulation of (20) could have been

$$h_{Ei}(0) = (h_{Vi}(0) - \in_{Vi}(0))v_0 - g_{Ei}(0) - \left(\in_{Ei}(0) - q_0 \in_{Vi}(0)\right) \quad (21)$$

if V tokens were exchanged in the market prior to generating E tokens for free. Since the main message would not change much, we shall keep the formulation in (20).

As a numerical example of (20), suppose there are only two users, $i = 1,2$ and that both have $h_{Vi}(0) = 100$ with $v_0 = 0.02$. Hence, each of them can generate $100(0.02) = 2\ E$ tokens for free. Suppose now that user $i = 1$ is interested in increasing the number of V tokens while $i = 2$ wishes to increase her

number of E tokens. Then, for instance, $i = 1$ defines $h_{E1}(0) = 0.5 = g_{E1}(0)$ selling $\in_{E1}(0) = 1$ unit of E in the market while $i = 2$ sells $\in_{V2}(0) = 80\ V$ tokens, which means that at the market equilibrium it is $q_0 = \frac{1}{80} = 0.0125 < 0.02 = v_0$. This means that in the internal market, one V token can buy a number of E which is lower than the rate at which E tokens are freely generated from V tokens. In any case, there is a substantial difference between the two ways to obtain E tokens. Indeed, in the market users would have to pay to buy E which instead can be generated for free from V in the wallet.

Continuing with the above example, this last statement translates into the definition of $h_{E1}(b)$ for $b = 1$ as follows

$$h_{E1}(1) = h_{E1}(0) + h_{V1}(1)v_1 - g_{E1}(1) - \left(\in_{E1}(1) - q_1 \in_{V1}(1)\right) \quad (22)$$

where $h_{V1}(1) = h_{V1}(0) + \frac{\in_{E1}(0)}{q_0} = 100 + \frac{1}{1/80} = 180$ and $h_{E1}(0) = 0.5$. Therefore if, for instance, it is also $v_1 = 0.02$, then user $i = 1$ could generate for free $180(0.02) = 3.6\ E$ tokens, which added to $h_{E1}(0) = 0.5$ would lead to an amount of $4.1E$ tokens available, after validation of block $b = 1$.

Likewise, it is immediate to see that $h_{V2}(1) = h_{V2}(0) - \in_{V2}(0) = 100 - 80 = 20$, and assuming as an example that $h_{E2}(0) = 1 = g_{E2}(0)$ and $v_2 = 0.02$ it follows that $h_{V2}(1)v_2 = 20(0.02) = 0.4\ E$ tokens which added to $h_{E2}(0) = 1$ and $\in_{E1}(0) = 1$ provides a total of $2.4\ E$ tokens.

The above example illustrates the obvious, though fundamental, point that an exchange market can exist if users have different preferences. If they both would have wished to sell/buy E tokens no exchange could have taken place. In the next section we begin introducing also an external exchange for V tokens.

2.5 Exchanging V and E tokens in external and internal markets

Take again $b = 0$ and now let's consider that V tokens could also be purchased in exchange, external, nodes against a fiat currency (say $US\ \$$) at price $r_0 = \frac{V}{\$}$, and not only in the internal exchange market against E. In this case those users owning both $\$$ and E, if interested in V, would have the opportunity to purchase them either in the external, or in the internal, exchange or in both. Hence, if they want to buy z units of V tokens with $\$$ they would need an amount of $x\$$, such that $xr_0 = z$. Instead, if they decide to buy z units of V with E they would need y units of E such that $\frac{y}{q_0} = z$.

Notice that since, by definition, q_0 is defined in terms of $\frac{E}{V}$, that is the price of E in terms of V, then $\frac{1}{q_0}$ is the internal market price of V in terms of E. Therefore, it will have to be $xr_0 = \frac{y}{q_0}$ alternatively, $(\frac{y}{x})(\frac{1}{q_0}) = r_0$. Namely, the external market equilibrium price should be positively related to the internal

market price, through the multiplying constant $\frac{y}{x}$. It follows immediately that $r_0 = \frac{1}{q_0}$ if and only if $x = y$, which would imply that $1\$$ and $1E$ would buy the same number of V tokens.

The above discussion preludes to the next section, where we are going to present the possibility of speculative trades.

3. *Multiplier effect, dual pricing* and speculation

In this section we explore an intrinsic feature of dual tokens blockchains, when both tokens can be traded in some market, and one of the two tokens can be obtained for free by holding units of the other token. As above, in what follows we start considering that V can be traded in the external market as well as in the internal market, against E only, while E can be exchanged exclusively in the internal market. We begin identifying the so-called multiplier effect of the internal market.

3.1 The multiplier effect of the internal exchange market

The introduction of an internal exchange market, between E and V, gives rise to a number of interesting phenomena. In this part we focus on what we define to be a *multiplier effect* on V and E, generated by the presence of such market. Indeed, consider again $b = 0$ and suppose $h_{Vi}(0)$ is chosen by user i. Then assuming $v = v_b > 0$, $q = q_b > 0$ and, to simplify the exposition, no transaction fees she could generate a number $h_{Vi}(0)v$ of E tokens for free which she can re-sell, before validation of block $b = 1$, to obtain additional $\frac{h_{Vi}(0)v}{q}$ units of V tokens. Therefore, she would now have a total of V tokens equal to $h_{Vi}(0) + \frac{h_{Vi}(0)v}{q}$.

Everything else being the same, in the next block $b = 1$ she could generate for free a number of E tokens equal to $(h_{Vi}(0) + \frac{h_{Vi}(0)v}{q})v$ which can be re-sold immediately to obtain an additional number $(h_{Vi}(0) + \frac{h_{Vi}(0)v}{q})\frac{v}{q}$ of V tokens and a total number of V units equal to $h_{Vi}(0)(1 + \frac{v}{q})^2$. It can be easily checked that by iterating the above procedure, until the generic $bth > 1$ block, we obtain that the total number of V units at block b is given by $h_{Vi}(0)(1 + \frac{v}{q})^{b+1}$. Since $\left(1 + \frac{v}{q}\right) > 1$, for given v and q, as b becomes large the expression $(1 + \frac{v}{q})^{b+1}$, in principle, may become infinitely large.

Hence the initial quantity of V, by means of iterated exchanges, is multiplied into a larger quantity by the factor $(1+\frac{v}{q})^{b+1} \geq 0$, that we could call the *V multiplier* which, under our assumption, could be equal to 1 only if $v = 0$ or $q = \infty$.

In reality such an ever-growing quantity of V would be impossible, since the number of V units is limited. Moreover, transaction fees could also discourage repeated trades. Additionally, even if the number of V could grow indefinitely, it is very unlikely to take place because we do not expect v and q to remain constant over time. As a matter of fact, to prevent so a policy measure by the platform could be to reduce v_b as the number of blocks increase. Additionally, q_b may tend to increase due to a systematic increase in demand for V against E.

Yet, the finding may be interesting to gain insights on the implications of an internal exchange market.

Finally, notice that users may be interested in implementing the above trades if the expected rate of return is at least as large as that of alternative investments. For example, suppose all is as above and that the user would sell $h_{Vi}(0)$ units of V in the market to obtain $\frac{h_{Vi}(0)}{r}$ units of US \$. The dollars could then be invested in an asset which provides an interest rate of $\rho > 0$ per block. Then the return rate of such investment, after b blocks, would be $(1+\rho)^{b+1} - 1$, while the return rate originated by the multiplier effect is $(1+\frac{v}{q})^{b+1} - 1$. Therefore, if $\rho > \frac{v}{q}$ the user would prefer to invest in the alternative asset rather than exploiting the multiplier effect, the opposite would occur if $\rho < \frac{v}{q}$ while if $\rho = \frac{v}{q}$ she would be indifferent.

3.2 The dual price of E tokens

The argument behind the multiplier effect can be borrowed to originate what, in this paragraph, we define to be the *dual price* phenomenon of E tokens. When both the internal and external markets for V are considered, while E can be traded only in the internal market, the possibility of an *asymmetry* in the "price" of E tokens, in terms of the fiat currency \$, could emerge in different circumstances.

In what follows we start investigating what we define to be the *weak dual price* version of such asymmetry. Consider a generic block b. Then, suppose the user has only 1\$, no V and no E in her wallet. With 1\$ it is possible to obtain r_b units of V, where r_b is the price of V expressed as $\frac{V}{\$}$ and then the number $r_b v_b$ of E, at no additional costs besides the initial dollar. We shall call this version of the dual price *weak* because we assume the user sells no V to buy E.

Likewise, suppose now a user owns $r_b v_b$ units of E, no units of V and no \$. Then to purchase \$ she first needs to buy V tokens, obtaining a number of units equal to $\frac{r_b v_b}{q_b}$. Subsequently she can buy a number of \$ units equal to $\frac{r_b v_b}{r_b q_b} = \frac{v_b}{q_b}$\$. Therefore, if $v_b \neq q_b$ a user investing 1\$ in E tokens would obtain a number of \$ units different from 1, when re-selling back the generated E tokens to purchase \$. This leads to the following, fundamental, E tokens *weak dual price* result

Proposition 1 (*Weak Dual Price***)** *Suppose $v_b \neq q_b$ and assume a user sells no V to buy E. Then the "price" in \$ of E tokens is different from the inverse of the "price" in E tokens of \$.*

Proof Immediate. Indeed, with 1\$ it is possible to buy $r_b v_b$ units of E tokens; hence the "price" in \$ of E tokens is $r_b v_b$. However, with 1 unit of E it is possible to purchase $\frac{1}{r_b q_b}$ units of \$, therefore the "price" in E tokens of \$ is $\frac{1}{r_b q_b}$ and its inverse equal to $r_b q_b$, which differs from $r_b v_b$ unless $q_b = v_b$.

Some comments are in order. First, the term "price" in the statement is in inverted commas because there is no *direct* external market, node, where \$ and E can be traded. That is, it is possible to purchase E with \$ and viceversa but only *indirectly*, namely through buying and selling V as an intermediate step.

Then, interestingly, the condition for the existence of a dual price is independent of r_b. That is, the *dual price* can take place regardless of the fiat currency, or cryptocurrency, considered and of its price for V. Therefore, despite the fact that a fiat currency is needed to formulate the proposition, the presence of a dual price would concern only the internal functioning of the platform. Notice that the absence of a weak dual price $v_b = q_b$, will imply a V multiplier equal to $(1 + \frac{v}{q})^{b+1} = (2)^{b+1}$ hence, with v and q constant, of potential opportunities to increase the amount of V tokens.

Finally, the existence of a *weak dual price* may generate arbitrage, speculation, opportunities by transacting \$ for E tokens, or the contrary. For example, suppose $v_b > q_b$; then, it follows that by investing 1\$ in V, and then V in E, the user can obtain more than 1\$ when selling back E tokens.

Instead, if $v_b < q_b$ it would not be profitable for the dollar owner to buy V tokens, generate E to sell them back and obtain dollars again, because it would receive less than one dollar in this case. In case $v_b = q_b$ the user will be indifferent.

What may be an intuition for the presence of a dual price? Here are two possible reasons. First the asymmetry existing between V and E; that is, V freely generates E while the contrary is not true. Secondly, there is no market for exchanging *directly* E with \$, but only indirectly through V.

But how long such speculation opportunity could be available for? In case $v_b > q_b$ the possibility to obtain more than 1\$ by investing 1\$ is likely to generate a demand for buying V with E, which would

tend to increase q_b, that might converge to v_b. Therefore, according to this argument, speculation may not last for long although, in the short run, such "arbitrage" activity might be profitable for users.

It is also possible to consider a *strong* version of the dual price, based on the following idea. Suppose the user has $1\$$ with which she purchases r_b units of V. Then, with r_b units of V she can generate for free $r_b v_b$ units of E, as in Proposition 1, but also buy $r_b q_b$ additional units of E by selling all her V tokens in the internal exchange market. As a result, with $1\$$ she can obtain as many as $r_b(v_b + q_b)$ units of E.

Assume now the user owns $r_b(v_b + q_b)$ units of E which she sells to buy $\frac{r_b(v_b+q_b)}{q_b}$ units of V and, subsequently $\frac{r_b(v_b+q_b)}{r_b q_b}\$ = \frac{(v_b+q_b)}{q_b}\$ \geq 1\$$. Following a reasoning analogous to the above one, this allows us to formulate the next result

Proposition 2 (*Strong Dual Price***)** *Suppose $v_b \neq 0$ and assume a user sells all of her V tokens to buy E tokens. Then the "price" in $\$$ of E tokens is always higher than the inverse of the "price" of $\$$ in E tokens.*

According to the above proposition, unless $v_b = 0$ the user can always make positive profits by selling $\$$ for E and re-buying $\$$ with E, even if $v_b = q_b$. Indeed, the user's rate of return in this case will be

$$\frac{(v_b + q_b)}{q_b} - 1 = \frac{v_b}{q_b} > 0 \quad (23)$$

Unlike Proposition 1, in this case $v_b = q_b$ does no longer represent indifference for speculating but simply says that the return rate from an initial investment of $1\$$ will be 100%. To conclude, observe that in between the weak and strong versions of price duality there could be *intermediate* forms of duality, when rather than selling no V, as in Proposition 1, or all the V units, the user sells part of them.

Indeed suppose, for example, that again the user has just $1\$$ with which she buys r_b units of V. Then $r_b v_b$ units of E are generated for free while a share sr_b of V, with $0 < s < 1$, is sold to obtain a total of $r_b(v_b + sq_b)$ units of E. Now assume the user sells back E to buy $\frac{r_b(v_b+sq_b)}{q_b}$ units of V which can be sold, together with those already in the wallet, $(1-s)r_b$, to obtain a total of $\frac{r_b(v_b+sq_b)}{q_b r_b} + \frac{(1-s)r_b}{r_b} = \frac{(v_b+q_b)}{q_b}\$$ as in the Proposition 2. Therefore, this shows that the number of $\$$ that can be obtained by re-selling V in this case is independent of the number of V that are converted in E, as long as even a minimum number of them are converted.

Alternatively, if the $(1-s)r_b$ units of V would not be sold to buy \$ then the user could purchase $\frac{(v_b+sq_b)}{q_b}$ \$ which is in general different from 1\$ unless $q_b = \frac{v_b}{(1-s)}$.

3.3 The external, direct, market for E tokens

In this last part of the section we introduce an additional market, that is the possibility to buy directly E on the external market against \$. Our goal is to discuss the implications of such market on the relevant trading prices. Suppose, again, a user has 1\$ and nothing else; moreover, suppose the user sells no V in the *internal* market to obtain E. Assume that w_b is the price of E in the external, direct, market, hence expressed in terms of $\frac{E}{\$}$; therefore, 1\$ generates w_b units of E. So now a user can either buy directly, or indirectly, E. If she buys directly she could obtain, as said, w_b units of E. If she buys indirectly, she first needs to purchase V at price r_b to generate $r_b v_b$ units of E. Therefore, a necessary condition for both markets to coexist is that the number of E units, bought directly or indirectly, would coincide.

This implies $w_b = r_b v_b$. However, suppose now the user has $w_b = r_b v_b$ units of E and wants to buy \$. She could do this directly in the external market obtaining $\frac{w_b}{w_b} = 1\$$. If instead she buys indirectly she would first need to purchase V tokens at price q_b, obtaining $\frac{w_b}{q_b}$ units of V, and then sell V to obtain $\frac{w_b}{q_b r_b}$\$. It follows that $\frac{w_b}{q_b r_b} = 1\$$ requires $\frac{r_b v_b}{q_b r_b} = \frac{v_b}{q_b} = 1\$$ and therefore $v_b = q_b$. Hence, when adding a direct market the condition to prevent a weak dual price, when the price of E in terms of \$ is the same in both the direct and the indirect markets, coincides with the condition without the direct market. Hence, whether with one or two markets the request to prevent weak dual pricing is the same. Analogous considerations hold also for the strong dual price version.

The above discussion provides a suggestion for policy making by the platform. If speculative trades are undesirable for the blockchain then the value of v should be calibrated in such a way to minimize them, by fixing a value around the market price.

4. Transaction costs stability

As already mentioned in the introduction, a main reason for a blockchain to issue a second token is to prevent transaction costs from being volatile, in terms of fiat currencies, as it would occur if the payment was in term of the principal native token. This is because the main token is traded in

exchange nodes where prices are volatile: hence, in turn, transaction costs in fiat currencies would also be subject to volatility. The point is made clear by the following quotation, drawn from the VeChain White Paper (2019):

"*The design of the two-token model intends to maintain stable and predictable transaction cost (in fiat) of using the VeChainThor blockchain*" (italics is mine)

However, the second token can guarantee stability of transaction costs if it is not traded in the market since, otherwise, its price would also be subject to market volatility. As a consequence, if both tokens are traded in the market, transaction costs stability can take place only under very specific conditions.

In this section we are going to investigate the stability issue, along two alternative interpretations of stability:

i) First, we shall consider the stability of the total transaction costs, paid in fiat currency, over subsequent blocks. That is, the number of $, or any other fiat currency, needed to pay for the transaction costs should remain about the same across blocks.

ii) According to the second line of investigation, we shall consider as stable the E tokens market price. Indeed, this would guarantee that the ratio between the total transaction costs paid in E tokens, over subsequent blocks, will not be affected by the possible fluctuations of the E tokens market price, expressed in fiat currency.

Intuitively, the last statement implicitly suggests that to achieve the above goal the gas price and the E tokens market price should relate with each other, in a specific and balanced way. This point is very important to keep in mind in the platform policy making, which we are going to discuss below.

4.1 The framework

Prior to setting up the framework it is important to introduce the following point. Inspired by Ethereum, in VeChain and other two-token platforms, every operation on the blockchain has a cost expressed in terms of Gas, which is the unit of measurement introduced for that. Gas is paid in terms of E, with users submitting a price expressing how many E tokens they are willing to pay for one unit of Gas.

Therefore, to start building up the framework we start reminding the following simple formula, drawn also from the VeChain White Paper (2019)

$$g_E(b) = p_b G_b \quad (24)$$

expressing the demand of E tokens for gas payment at block b. In (24) p_b, with units of measurement $\frac{E}{G}$, is the average unit price of gas in terms of E tokens proposed by users to include their transactions in block b, and G_b the total number of gas units needed to implement those transactions.

i) We begin the analysis considering the first line of investigation. Below we translate the stability requirement into the following, simple, formula related to two consecutive blocks

$$p_b G_b w_b = p_{b+1} G_{b+1} w_{b+1} \quad with\ b = 0,1, \ldots . (25)$$

where, as above, w_b is the E tokens market price expressed in terms of a fiat currency, say \$, with unit of measurement $\frac{\$}{E}$. From (25) it clearly emerges that, to satisfy (25), the *gas price* and the *market price* must be appropriately related.

More specifically, if $D_E(b)$ and $S_E(b)$ are, respectively, the market demand of E tokens at block b expressed in \$, and the market supply of E tokens against \$ at block b then

$$w_b = \frac{D_E(b)}{S_E(b)} \quad (26)$$

where, as we shall see, $S_E(b)$ will be given by the number of E tokens circulating within the platform at block b minus the E tokens used for gas and minus those held in the users' wallets at each block, $h_E(b)$.

Finally we assume that $h_V(b) = h_V$, that is the total number of V tokens in the system is constant across the blocks, and that $v_b = v$, namely the rate at which E tokens are created from V tokens, is also the same across the blocks. Therefore, $h_V v$ is the number of new E tokens created at each block in the platform.

To start gaining insights on the implications of (26) consider two consecutive blocks. For simplicity we take the initial block $b = 0$ and block $b = 1$.

Then from (25) we obtain

$$p_0 G_0 w_0 = p_1 G_1 w_1 \quad (27)$$

Assume, again for simplicity, that E can only be exchanged on the *external* market. Therefore, $S_E(0) = h_V v - p_0 G_0 - h_E(0)$ and $S_E(1) = h_V v + \lambda p_0 G_0 - p_1 G_1 - h_E(1)$, where $0 < \lambda < 1$ is the *share* of the transaction costs paid by users at $b = 0$ as a reward to *block validators*.

At $b = 1$, the amount $\lambda p_0 G_0$ is available in the platform together with the newly created number of E tokens, $h_V v$. The remaining $(1 - \lambda)$ share of the paid transaction costs are burnt and eliminated from circulation. For example, in VeChain it is $\lambda = 0.3$.

Hence

$$w_0 = \frac{D_0}{s_E(0)[h_V v - p_0 G_0 - h_E(0)]}; \frac{D_1}{s_E(1)[h_V v + p_0 G_0 \lambda - p_1 G_1 - h_E(1)]} = w_1 \quad (28)$$

with $h_V v - p_0 G_0 - h_E(0) > 0, h_V v + p_0 G_0 \lambda - p_1 G_1 - h_E(1) > 0$ and where $0 \leq s_E(0), s_E(1) \leq 1$ stand for the share of the total quantity of E traded in the market against \$, respectively, at block $b = 0$ and $b = 1$, while $D_E(0) = D_0$ and $D_E(1) = D_1$. The remaining shares $(1 - s_E(0))$ and $(1 - s_E(1))$ would be transferred through the blockchain across users.

Defining $D_{01} = \frac{D_0}{D_1}, s_{01} = \frac{s_E(0)}{s_E(1)}$ from (28) it follows that

$$\frac{w_0}{w_1} = \frac{D_{01}(h_V v + p_0 G_0 \lambda - p_1 G_1 - h_E(1))}{s_{01}(h_V v - p_0 G_0 - h_E(0))} \quad (29)$$

But (27) implies

$$p_1 = \frac{p_0 G_0 w_0}{G_1 w_1} \quad (30)$$

so that replacing (30) into (29), and solving for $\frac{w_0}{w_1}$, we obtain

$$\frac{w_0}{w_1} = \frac{D_{01}(h_V v + p_0 G_0 \lambda - h_E(1))}{s_{01}(h_V v - p_0 G_0 (1 - \frac{D_{01}}{s_{01}}) - h_E(0))} \quad (31)$$

and from (30) it follows that

$$p_1 = \frac{D_{01}(h_V v + p_0 G_0 \lambda - h_E(1))}{s_{01}(h_V v - p_0 G_0 (1 - \frac{D_{01}}{s_{01}}) - h_E(0))} \frac{G_0}{G_1} p_0 \quad (32)$$

Equation (32) shows how, even in the simplest case of two blocks, to satisfy (27) the gas price must evolve according to a very specific, and composite, function of several quantities. To have a better appreciation of (32) below we consider some particular cases. However, before doing so it is worth noticing that (32), keeping everything else as fixed, is an increasing function of $\frac{D_{01}}{s_{01}}$ which tends to 0 as $\frac{D_{01}}{s_{01}}$ goes to 0 and tends to

$$p_1 = \frac{\left(h_V v + p_0 G_0 \lambda - h_E(1)\right)}{G_1} \quad (33)$$

as $\frac{D_{01}}{s_{01}}$ goes to infinity.

4.2 A benchmark case: $D_{01} = 1 = s_{01}, G_0 = G = G_1, h_0 = 0 = h_1$ with two blocks.

To obtain some further insights on the implications of (27), in this paragraph we assume that the transactions in the two blocks require the same number of gas units, the demand for E is constant over the two blocks as well as the ratio of supply shares, and there are no monetary holdings.

Suppose $w_0 > w_1$ that is the market price decreases in $b = 1$, hence E becomes *weaker* as compared to \$. For (27) to hold, such decrease in the market price must be compensated by an increase in the gas price $p_0 < p_1$ in such a way that

$$p_1 = \frac{w_0}{w_1} p_0 \quad (34)$$

Therefore, the platform should induce users to propose a higher unit gas price, and (34) suggests that it should be larger than p_0, by the multiplying constant $\frac{w_0}{w_1}$.

For given G, as compared to block $b = 0$, a higher gas price at $b = 1$ has two main Implications. First, it increases the demand of E tokens needed to implement transactions and smart contracts. Secondly, it increases the share of transaction costs going to the block validators, since $p_1 G\alpha > p_0 G\alpha$.

From (28), assuming $D_E(0) = D = D_E(1), s_E(0) = s = s(1), S_E(0) = S_0 > 0, S_E(1) = S_1 > 0$, we now have

$$w_0 = \frac{D}{S_0} = \frac{D}{h_V v - p_0 G}; \frac{D}{h_V v + p_0 G\lambda - p_1 G} = \frac{D}{S_1} = w_1 \quad (35)$$

Expression (35) makes it clear that, to satisfy (28), the E market price and the gas price at $b = 0$ are positively related at block $b = 0$ but negatively related at $b = 1$. Likewise, the market price at $b = 1$ is positively related with the gas price at $b = 1$. In a more general framework, we claim that there is a positive relation at the same block and a negative relation at the follow up blocks.

Now suppose, as above, that $w_0 > w_1$ which requires $h_V v - p_0 G < h_V v + p_0 G\lambda - p_1 G$ and so $p_1 < p_0(1 + \lambda)$. Hence, the market price can decrease if the gas price does not increase too much at block $b = 1$, with an upper bound of $p_0(1 + \lambda)$.

However, from (34) it must be $p_1 = \frac{w_0}{w_1} p_0$. Replacing p_1 with $\frac{w_0}{w_1} p_0$ in (35), and solving for $\frac{w_0}{w_1}$ it follows that $\frac{w_0}{w_1} = 1 + \frac{p_0 G\lambda}{h_V v}$, hence,

$$p_1 = p_0 \left(1 + \frac{p_0 G\lambda}{h_V v}\right) \quad (36)$$

It is immediate to verify that (36) satisfies the inequality $p_1 < p_0(1+\lambda)$ and therefore, according to the above argument, should be the expression of p_1 needed for (27) to hold.

Within the limits of our model, to satisfy (28) the price p_1 must be a quadratic function of p_0, positively related to the share λ accruing to block validators, to the needed gas G and inversely related to the number Vv of generated E tokens.

Admittedly the above model, and related findings, are based on simplifying assumptions: constant G and D over *only* two blocks. Yet, despite these simplifications, the findings can provide some useful initial insights for policy making.

For example, since the rate v can in principle be changed by the platform, (36) suggests that, again within the assumptions of the model, a way to curb a trend of a gas price increase could be to increase v, or decrease the gas units G needed to implement transactions or even reduce the share of transaction costs, paid to block validators, to below λ.

Before extending the analysis, by relaxing some of the model assumptions, it is interesting to complete the investigation considering also the case of $w_0 = w_1$ and $w_0 < w_1$. As for $w_0 = w_1$ is concerned, by the same line of argument used for $w_0 > w_1$ it is immediate to see that it should be $p_1 = p_0(1+\lambda)$. However, equation (28) would imply $w_0 = w_1(1+\lambda)$ which cannot be the case since we assumed $w_0 = w_1$. Therefore, it could not be possible to satisfy (28) with a constant market price for E. It is immediate to verify that such impossibility will hold also with $w_0 < w_1$, that is when the market price increases. These findings are of course based on our specific assumptions, and below we shall discuss whether or not they would maintain when relaxing some of such assumptions.

4.3 Constant demand, constant supply shares, constant gas and no money holding with any number of blocks

In this paragraph we start extending the previous model, first introducing a third block, $b = 2$ and then generalising to any number of blocks. In this case equation (28) would become

$$p_0 G w_0 = p_1 G w_1 = p_2 G w_2 \quad (37)$$

It can easily be checked that the only possibility to satisfy (37) is $w_0 > w_1 > w_2$ and that

$$p_2 = \frac{w_1}{w_2}\frac{w_0}{w_1}p_0 = \frac{w_0}{w_2}p_0$$

It also follows that $\frac{w_1}{w_2} = \frac{\left(1+\frac{(p_0+p_1)G\lambda}{h_V v}\right)}{\left(1+\frac{p_0 G\alpha}{h_V v}\right)}$ hence

$$p_2 = \left(1 + \frac{(p_0 + p_1)G\lambda}{h_V v}\right) p_0 \quad (38)$$

Finally, extending to a generic number of blocks B we obtain

$$p_B = \left(1 + \frac{(p_0 + .. + p_{B-1})G\lambda}{h_V v}\right) p_0 \quad (39)$$

The above considerations can be summarised as follows

Proposition 3 *Suppose in the blockchain the market demand for E tokens, the supply shares and gas consumption for blocks are constant and that users have no wallet holdings. Then transaction costs (in fiat) are constant only if the market price for E tokens is decreasing and the gas price increasing.*

The economic intuition behind the previous indication is as follows. Under the assumptions of constant market demand, constant supply shares, constant gas consumption and no wallet holdings, the supply of E tokens increases at every block, because of the λ share of E tokens paid for gas being distributed and kept into circulation. As a consequence, the market price must decrease and, in order for transactions fees to be constant, the gas price would increase since E tokens are now cheaper. The gas price dynamics must evolve according to (40) for the transaction costs to remain constant in fiat currency.

4.4 The general model with any number of blocks

In this paragraph we now extend the previous analysis to any number of blocks, assuming any non-negative values for G_b, $G_{b+1}, D_E(b), D_E(b+1)$, $s_E(b), s_E(b+1), h_E(b), h_E(b+1)$. Start considering again, for convenience, equation (33) for blocks $b = 0,1$, which we re-write below

$$p_1 = \frac{D_{01}(h_V v + p_0 G_0 \lambda - h_E(1))}{s_{01}(h_V v - p_0 G_0 (1 - \frac{D_{01}}{s_{01}}) - h_E(0))} \frac{G_0}{G_1} p_0 \quad (40)$$

we can immediately see that it could be $w_0 > w_1$ also with $p_0 > p_1$. Indeed, since now p_1 depends on several quantities, equation (40) can be satisfied with a variety of different values of p_1. In fact, if $\frac{w_0}{w_1} > 1$ but $\frac{G_0}{G_1} < \frac{w_1}{w_0}$, which can take place when either G_0 is sufficiently small, or G_1 sufficiently large, or both, then $p_0 > p_1$. The same can occur for example if, for finite G_0 and $G_1 > 0$, it is $\frac{w_0}{w_1} \sim 0$

because $h_E(1) \sim h_V v + p_0 G_0 \lambda$, since in this case $p_1 \sim 0 < p_0$. Intuitively, if basically no E token is supplied in the market, at block $b = 1$, then w_1 would meaningfully grow and p_1 has to decrease to satisfy (40), compensating for the higher cost of tokens.

Extending (40) to any number of blocks we obtain

$$\frac{w_0}{w_B} = \frac{D_{0B}(h_V v + (p_0 G_0 + .. + p_{B-1} G_{B-1})\lambda - p_B G_B - h_E(B))}{s_{0B}(h_V v - p_0 G_0 (1 - \frac{D_{0B}}{s_{0B}}) - h_E(0))} \quad (41)$$

where $D_{0B} = \frac{D_E(0)}{D_E(B)}$, $s_{0B} = \frac{s_E(0)}{s_E(B)}$ hence

$$p_B = \frac{D_{0B}(h_V v + (p_0 G_0 + .. + p_{B-1} G_{B-1})\lambda - p_B G_B - h_E(B))}{s_{0B}(h_V v - p_0 G_0 (1 - \frac{D_{0B}}{s_{0B}}) - h_E(0))} \frac{G_0}{G_B} p_0 \quad (42)$$

4.5 *Stable price of E tokens*

In this paragraph we consider the second line of investigation of the above stability quotation which, given the previous discussion, it is immediate to formulate as follows

$$w_B = w_{b+1} \text{ with } b = 0,1,2, \ldots \quad (43)$$

Equation (43) would guarantee that the ratio of transactions costs paid in E tokens, over different blocks, will not be affected by the E tokens market price fluctuations. That is, E in this case would act as a stablecoin changing at a fixed rate, typically one-to-one to a fiat currency. However, empirical evidence on the market price dynamics suggests that w_b, for example in VeChain and NEO, has varied extensively over the year 2022, suggesting that stability policy (43) may not be easy to implement. Below we discuss the reasons for such difficulty.

As above, start considering block $b = 0$ and $b = 1$. Then, (43) is satisfied when

$$w_0 = \frac{D_0}{s_E(0)[h_V v - p_0 G_0 - h_E(0)]} = \frac{D_1}{s_E(1)[h_V v + p_0 G_0 \lambda - p_1 G_1 - h_E(1)]} = w_1 \quad (44)$$

Differently from (32), to maintain the stability of the E token market price, we now obtain the following expression relating the gas prices over the initial two blocks

$$p_1 = Max(0; \frac{(h_V v - h_E(1))}{G_1} - \frac{s_{01}(h_V v - h_E(0))}{D_{01} G_1} + p_0 \frac{G_0}{G_1}\left(\lambda + \frac{s_{01}}{D_{01}}\right)) \quad (45)$$

suggesting that p_1 needs to *increase linearly* with respect to p_0, where the slope of the line is given by $\frac{G_0}{G_1}\left(\lambda + \frac{s_{01}}{d_{01}}\right)$. This is unlike equation (32), where p_1 turns out to be a *quadratic function* of p_0. To gain some insights on the difference between (32) and (45) compare them, for example, with respect to the benchmark case of $D_E(0) = D = D_E(1), s_E(0) = s = s_E(0), S_E(0) = S_0 > 0, S_E(1) = S_1 > 0$. As for (36) we obtain then

$$p_1 = p_0(1 + \lambda) \quad (46)$$

which, for $h_V v > p_0 G$ is strictly larger than (36). That is, to satisfy (46) p_1 has to increase more than with the stability policy established by (32).

It is simple to verify that expression (45) can be extended, to generic blocks b and $(b+1)$, as follows

$$p_{b+1} = Max\left(0; \frac{\left(h_V v - \lambda \sum_{i=0}^{b-1} p_i G_i - h_E(b+1)\right)}{G_{b+1}} - \frac{s_{b(b+1)}\left(h_V v - \lambda \sum_{i=0}^{b-1} p_i G_i - h_E(b)\right)}{D_{b(b+1)} G_{b+1}} + p_b \frac{G_b}{G_{b+1}}\left(\lambda + \frac{s_{b(b+1)}}{D_{b(b+1)}}\right)\right) \quad (47)$$

The "stability" analysis conducted in this section, whether according to (32) or to (47), suggests a key element in two-token blockchains. That is, if the platform wants to pursue some transaction costs *stability policy* then it should be aware of the delicate balance, relation, that has to take place between the E token market price w_b and the gas price p_b. Indeed, if such relation is not satisfied the policy may not succeed. However, it is important to point out again that p_b is the block average price *chosen by the users*, while w_b is determined by the aggregate *supply and demand market conditions*.

As a result, the platform could neither *control directly* the market price *nor* the gas price, yet it could undertake actions to induce users to behave as the platform desires while, at the same time, leaving them with enough freedom in their choice.

For example, to implement the stability condition in (43), the gas price at block $(b+1)$ should be given by (47). This implies two types of issues. First users should need to gather a large volume of information, concerning the quantities which define p_{b+1}. Secondly, users have to decide to submit gas prices given by p_{b+1}. Therefore, even if the needed information is available, unless the market and/or the platform are inducing the users to act appropriately, they may not propose p_{b+1} as defined in (47), and the blockchain stability policy fail to succeed.

4.6 Some Empirical Evidence

As a follow up to the above theoretical analysis on stability, in this paragraph we undertake a simple empirical investigation considering a small sample of data from VeChain Explorer. There was no particular reason to choose such sample, except from gaining some insights on how our analysis matches with observations. For this reason, the evidence that we discuss can only be considered as a minor contribution to the issue. This to check if and what kind of stability can be observed in gas payment for blocks. Data refer to two groups of 10 blocks, both extracted from the VeChain platform on 25 September 2025, with the timing of blocks validation differing by about $4h, 15\ mins$ from each other.

This short time interval was chosen to keep the E market price relatively stable, allowing us to observe possible differences in gas payment due to either the gas unit price, or to the demand of gas or to both.

That is, we shall consider the stability condition discussed in paragraph 4.5. However, we shall not be able to check whether the stability of the E tokens market price is due to the specific relations in (45) and (47) or to alternative reasons. This is because the unit price of gas is also basically stable, and while the VeChain Explorer provides data on blocks gas consumption, it provides no data on the market demand for E tokens, and the users' holdings. Hence, we cannot fully verify whether (45) and (47) explain the stability for E market prices.

Table 1 below contains the main quantities related to Group 1 blocks. In the Table the symbol BN stands for the block number, TE stands for the total number of E units spent for the block, G stands for the total gas used, GL the gas limit per block, equal to $40.000.000$ gas units per, TG stands for total gas, BYTES stands for the number of bytes occupied by the transactions of that block.

The E market price, for Group 1 blocks, was around $0.00137€$, and despite a slightly decreasing trend that is taking place in the last few weeks, we could consider the price as constant over the blocks, and condition (43) satisfied. Indeed, as we are going to see below, if the E tokens market price is constant then for condition (27) to be valid, when extended to all blocks, the total expenditure on gas should also be constant for each block, which in our sample is not the case. This is why, of the two stability notions that we discussed the relevant one is contained in Paragraph 4.5.

Table 1

Group 1 blocks

BN	TE	G/GL	G	BYTES	TE/G	TE/BYTES	TE/(G/GL)
22826099	117.48	28.26	11704000	45261	1,00376E-05	0,002596	4,01504
22826098	39.94	9.93	3972000	21518	1,00554E-05	0,001856	4,02215
22826097	37.97	9.47	3788000	20977	1,00238E-05	0,00181	4,00950
22826096	58.10	14.49	5796000	31150	1,00242E-05	0,001865	4,00967
22826095	24.33	6.07	2428000	14885	1,00206E-05	0,001635	4,00823
22826094	51.18	12.74	5096000	27434	1,00451E-05	0,001866	4,01805
22826093	44.97	11.21	4484000	30817	1,0029E-05	0,001459	4,01160
22826092	38	9.47	3788000	23117	1,00317E-05	0,001644	4,01267
22826091	48.44	11.61	4644000	21249	1,04307E-05	0,00228	4,17226
22826090	46.43	11.57	4628000	23537	1,00324E-05	0,001973	4,01296

The column TE shows that the total gas payment in E tokens, across the ten blocks is quite variable. This could either be due to variation of the total demanded gas per block, or to variation of unit gas price, or both. By considering column G we can see that gas consumption is quite variable while column $\frac{TE}{G}$ shows how the average unit price, in each block, is rather similar. Therefore, differences in the TE seems to be mostly induced by variations in gas consumption than by variations in the gas unit price.

Analogous considerations seem to characterize Group 2 blocks, for which the E market price was around $0.00138€$, whose main features are reported in Table 2 below.

Table 2

Group 2 blocks

BN	TE	G/GL	G	BYTES	TE/G	TE/BYTES	TE/(G/GL)
22827615	160.87	40	16000000	83007	1,00544E-05	0,001938	4,02175
22827614	32.32	8.05	3200000	18777	0,0000101	0,001721	4,04
22827613	57.43	14.31	5724000	32060	1,00332E-05	0,001791	4,01328
22827612	62.37	15.54	6216000	30718	1,00338E-05	0,00203	4,01351
22827611	41.66	10.38	4152000	26130	1,00337E-05	0,001594	4,01348
22827610	37.82	6.83	2772000	13843	1,00361E-05	0,00201	4,01443
22827609	81.85	20.40	8160000	44266	1,00306E-05	0,001849	4,01122
22827608	31.84	7.93	3172000	16289	1,00378E-05	0,001955	4,01513
22827607	37.56	9.36	3744000	26541	1,04321E-05	0,001415	4,0128
22827606	56.27	13.69	5476000	34421	1,02757E-05	0,001635	4,11030

5. Conclusions

Taking inspiration from the Vechain platform, which exhibits a structure analogous to other two-token blockchains, in the paper we analysed *three main economic issues* related to dual-token platforms. Therefore, our findings could be considered as valid, with possible appropriate adjustments, also for other dual-token platforms.

First, we provided a representation of the users' token holdings dynamics, depending upon whether or not both tokens are traded in the market. In the analysis we pointed out how the users' preferences over the tokens, formalized by utility functions, are going to play a major role in shaping their monetary holdings over time. The evolution of tokens' holdings represents a complete description of the system over time and provides crucial information for supporting the blockchain policy making.

Secondly, we discussed how the presence of *internal*, as well as *external*, markets where the two tokens are traded may generate potential *dual prices*, hence the possibility of speculative trading, between a fiat currency such as $ and the E token. That is, the exchange rate of $ against E may differ from the inverse of the exchange rate of E against $.

We also discussed how even only an *internal* exchange market, between the V token and the E token, may give rise to a *multiplying* effect. Namely by trading V against E, and viceversa, a number of times, under appropriate conditions the number of V tokens can meaningfully increase, according to a so-called *multiplier* coefficient. Therefore the main message of this part is that when both tokens are traded, and one of them can be obtained with no out of pocket payment, by holding the other, then speculative trades may take place, potentially destabilizing the platform. Such possibility is an intrinsic feature of dual-token blockchains which, to our knowledge, we were the first to discuss. Though, in reality, the likelihood of such speculative flows may be limited by price adjustment as well as by other conditions, we found it important to identify this as a fundamental property of two-token blockchains.

Thirdly, based on a main goal for having a second token in a blockchain, we investigated the possibility of paying transaction costs, fees, in one of the two tokens in such a way that, in fiat currency, costs will be the same, stable, across the sequence of blocks. The analysis suggested quite explicitly that transaction fees stability is not an easy target to achieve for a platform unless, as suggested by Mayer (2022), one token is a stablecoin. In this case, the token market price will be constant and gas expenditure will not be affected by its volatility. Indeed, the stability condition requires a specific relation between the token market price and the unitary gas price, expressed in tokens, a relation which depends on multiple quantities that for the platform are not easy to control. Therefore, the main goal of two traded tokens becomes the opportunity, for the users, to specify their preferences and needs by focusing their demand on a single token.

Data Availability Statement

· What data have been shared. VeChain Explorer
· Where they can be accessed (e.g., supplementary files or repositories). https://explore.vechain.org/it
· (If applicable, the reasons why any materials or data cannot be shared. Note: if there are no obstacles to sharing data, we expect authors to provide full access for the purposes of peer review). No obstacle

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