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Abstract

We suggest that flexible majority rules for currency issuance decisions foster the stability of a cryptocurrency. With flexible majority rules, the vote-share needed to approve a particular currency issuance growth is increasing with this growth rate. By choosing suitable parameters for these flexible majority rules, we show that optimal growth rates can be achieved in simple settings. Moreover, with flexible majority rules, changes in the composition of growth-friendly and growth-adverse agents only have a comparatively moderate impact on growth rates, and extreme growth rates are avoided. Finally, we show that optimal money growth rates are realized if agents entering financial contracts anticipate ensuing inflation rates determined by these flexible majority rules.

Keywords: Digital currency, central bank, voting, majority rule, flexible majority rules

JEL Classification: D72, E31, E42, E52, E58

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1 Introduction

Money is typically defined by its functions: It serves as a store of value, a medium of exchange, and a unit of account. Since the first currency was created, its value, in terms of purchasing power of goods and services, has been a key concern to its users. For example, money in the form of a rare commodity, such as gold or silver, had a good chance to achieve value stability as long as the commodity content of coins remained constant. Today, however, most currencies in the world are fiat money, which means that they neither have a real anchor nor are of limited supply by nature. The ways to foster price stability in such a setting are manifold and range from rules for monetary expansion¹ to the independence of central banks from day-to-day political processes, which is the currently-favored method.

At the same time, cryptocurrencies which are based on the distributed ledger technology and a particular mechanism to build a consensus on valid transaction have been developed. The expansion of the supply of such digital currencies can be directly embedded in their algorithms. For example, the Bitcoin protocol specifies an exogenous growth rate of the supply until a given limit is reached and all Bitcoins have been mined.

For the next generation of blockchain technology and cryptocurrencies, the question is which rules can be used to determine the growth rate of the currency. There are three options. First, a particular growth rate—maybe dependent on the current status of the use of the cryptocurrency—could be embedded in the algorithm. Second, the growth rate can be determined by a small group who either has developed the ledger technology or has been delegated by the participants to make such decisions. Third, currencyholders in the blockchain could decide democratically about the growth rate of the currency in each period.

In this paper, we explore the third option; democratically-governed currency issuance. Typically, participants in the blockchain have differing preferences regarding the growth rate. For instance, participants holding the currency as a store of value are interested in low or zero growth rates to maintain or increase the value of the currency. Participants who are engaged in verifying transactions may be interested in higher growth rates if the newly issued currencies are used to reward

¹Fisher (1920) made an innovative proposal for such a rule, and Hall (1997) discussed its possible implementation.

the verification tasks. Participants who have borrowed the cryptocurrency at some nominal interest rate are interested in much higher growth rates, as an inflated currency would reduce their repayment burden.

The question is whether democratic decision-making rules can guarantee the stability of a currency. This is a long-standing issue and there is considerable doubt whether standard democratic decision-rules could achieve this purpose. Using a simple majority rule, for instance, to decide on the issuance of new money, can produce polar results: High growth rates are obtained if there is a majority of net borrowers of the currency, who aim at lowering its future real value in order to decrease the real repayment burden. Zero growth is obtained if there is a majority of net savers who wants to increase the future value of the currency. Therefore, the crucial question is: Are there democratic procedures that keep the value of the currency constant—or approximately constant—in terms of purchasing power? In this paper, we suggest that appropriately-designed flexible majority rules may achieve this objective.

We use a simple model with deep conflicts among users of a currency. For the sake of simplicity, we assume that there is a positive relation between the growth rate and the inflation rate. This is clearly a simplification, since currency growth and inflation may be only weakly linked in the short term. The reason for this is that currency demand may fluctuate a lot. This is true for established public monies, and, of course, even more so for privately-issued cryptocurrencies for which the set of users and expectation about the viability of the cryptocurrency may fluctuate a lot.

We take the saver/borrower conflict as a leading example. However, the construction can be applied to any other conflict, as we will discuss in Section 4. Thus, if currency users can vote on such an outcome and if we abstract from further costs of inflation and deflation, borrowers would always vote for the highest-possible growth rate of issuance, and savers would always vote for the lowest-possible growth rate of issuance². Of course, in practice, savers can partly hedge against inflation risk, and borrowers may have to bear some inflation risk through inflation-linked loans. We assume that such countervailing forces are not fully offsetting the costs and benefits of inflation for savers and borrowers, respectively. Hence, savers bear some

²Workers who just signed wage contracts for a particular time frame have similar preferences regarding inflation.

inflation risk, while borrowers benefit from higher inflation.

With fixed majority rules for decisions on the issuance of new money, we may obtain extreme results—either high money growth rates associated with high inflation or zero growth and potential deflation. This situation can be improved by super-majority rules, as shown by Bullard and Waller (2004).

In this paper, we will construct a flexible majority rule for money issuance³ and argue that it can constitute an efficient democratic decision-making rule for issuance of a currency. With flexible majority rules, the vote-share needed to approve a particular currency issuance growth is increasing in the growth rate. The idea of a flexible majority rule for money growth decisions is that a small majority, or even a minority, can engineer a low growth rate, while large growth rates require the support of large majorities. By choosing suitable parameters for such flexible majority rules, we show that optimal growth rates can be achieved. Moreover, changes in the composition of borrowers and savers only have a comparatively moderate impact on growth rates, and extreme growth rates are avoided.

In this short paper, we do not address other critical points such as whether cryptocurrencies should be introduced at all and how a cryptocurrency may coexist and interact with the existing forms of money. These issues are discussed and evaluated in other works and we refer to Camera (2017), as well as Berentsen and Schär (2018) for a comprehensive evaluation of the potential and limitations of crypto- and digital currencies.⁴

The paper is organized as follows. Our model is described in Section 2, where we also provide the results for fixed majority rules. In Section 3, we provide the results for flexible majority rules. In Section 4, we discuss ways to apply flexible majority rules. In Section 5 we present some simple numerical examples. Section 6 concludes.

³See Gersbach (2017b) for a survey of flexible majority rules in general and Gersbach and Pacht (2008) for an application of flexible majority rules to a monetary union.

⁴For the design of a centrally-issued and democratically-governed digital currency, see Gersbach (2017a).

2 Model

2.1 The Set-up

We denote the number of individuals by N ($N \geq 3$). We call these individuals "citizens", as they have the right to vote on currency issuance and thus are part of the citizenry that collectively has the formal and de facto power to take currency issuance decisions. For cryptocurrencies, the citizenry could be defined as the set of all currency holders or currency borrowers. Typically, the citizenry changes over time. For simplicity, we assume that N is an odd number. There are B (net) borrowers ($N > B > 0$), and $N - B$ (net) savers. We denote the number of net savers by $S := N - B$. It does not matter whether the type of a citizen—borrower or saver—is private information or common knowledge.

Without loss of generality, we order the citizens in such a way such that citizens $i = 1, \dots, B$ are borrowers and citizens $i = B + 1, \dots, N$ are savers. Then, we assume that a borrower $i = 1, \dots, B$ has a utility function $u_B : \mathbb{R}_+ \rightarrow \mathbb{R}$ that is twice continuously differentiable, strictly increasing, strictly concave, and that satisfies

$$\lim_{g \rightarrow +\infty} u'_B(g) = 0, \quad (1)$$

where $g \geq 0$ denotes the money growth rate. Moreover, we assume that a saver $i = B + 1, \dots, N$ has a utility function $u_S : \mathbb{R}_+ \rightarrow \mathbb{R}$ that is twice continuously differentiable, strictly decreasing, strictly concave, and that satisfies

$$\lim_{g \rightarrow +\infty} u'_S(g) = -\infty. \quad (2)$$

We provide an economic rationale for the two limit Conditions (1) and (2) in Appendix B. The utility assumptions imply that borrowers prefer higher growth rates over lower growth rates of the currency. The opposite holds for savers. To measure welfare of the entire group of money users, called the citizenry, we introduce the utilitarian social welfare function

$$U(g) = Bu_B(g) + Su_S(g).$$

We note that U is strictly concave as it is a sum of strictly concave functions. Moreover $\lim_{g \rightarrow +\infty} U'(g) = -\infty$. Hence, $U(g)$ has a unique global maximum $\in [0, +\infty)$, which is either zero or a solution of the following equation:

$$Bu'_B(g) = -Su'_S(g). \quad (3)$$

We use g_{FB} to denote the welfare optimal growth rate.

It is straightforward to verify that u_B and u_S defined by $u_B(g) = \ln(g + 1)$ and $u_S(g) = -\alpha g^2$, where $\alpha > 0$, are examples of suitable utility functions. Using Equation (3), it is straightforward to show that in this example, the first-best level of issuance growth rate is given by

$$g_{FB} = \sqrt{\frac{1}{4} + \frac{B}{2\alpha S}} - \frac{1}{2}.$$

2.2 Voting Right and Voting Processes

We assume that each citizen has the right to cast one vote, which reflects the one-person-one-vote principle.⁵ We now consider two voting processes. Both consist of a sequence of voting rounds by the citizenry about an increasing level of issuance growth rate. The first voting process is called "fixed majority rule", as the threshold of the number of votes needed to accept a higher level of issuance growth rate is fixed. The second voting process is called "flexible majority rule". According to this voting process, the threshold of the number of votes needed to accept a higher level of issuance growth is increasing with the issuance growth rate. In Subsection 2.2.1, we give more formal details about the functioning of these voting processes, and in Subsection 2.2.2, we examine the performance of both.

2.2.1 Common Voting Features

We first define a voting process as a sequence of popular votes. The voting process starts with an initial value, which we denote by $g_L \geq 0$. In most applications, $g_L = 0$ may be the most sensible starting point. When paybacks and destruction of cryptocurrencies are part of the currency architecture, g_L could also be negative.

⁵In Section 4, we discuss how voting rights can be adjusted to different stakes on a blockchain with a proof-of-stake protocol.

Either the community votes for g_L or it votes for a higher growth rate given by $g_L + g_Z$, where $g_Z > 0$ is the increment in the growth rate. If g_L is agreed upon, the voting procedure stops and this value is chosen. If $g_L + g_Z$ is preferred over g_L , the voting procedure goes on with a choice between $g_L + g_Z$ and $g_L + 2g_Z$. We now formally define a voting process:

Definition 1

A voting process is a sequence of popular votes taking place together with an increasing sequence of thresholds $(M_k)_{k \in \mathbb{N}}$ defined iteratively in the following way: During the k^{th} popular vote, where $k \in \mathbb{N} = \{1, 2, \dots\}$, the following procedure takes place:

- *Citizens can vote either for the status quo, which is given by $g_L + (k - 1)g_Z$, or for $g_L + kg_Z$.*
- *The growth rate $g_L + kg_Z$ is kept as a future status quo for the next popular vote $k + 1$ if and only if more than a number $M_k \leq N$ of citizens votes in favor of it.⁶ If this is not the case, the issuance growth rate that is chosen by this voting process is given by $g_L + (k - 1)g_Z$.*
- *If the voting process does not stop, we will say that the issuance growth rate chosen by the voting process is an infinite issuance growth rate.*

Since citizens have polar preferences, i.e. they either support a zero growth rate or extremely high money growth rates, sincere voting is optimal for all citizens. We now define the voting processes based on fixed and flexible majority rules and examine their performances.

2.2.2 Majority Rules

A voting process based on a fixed majority rule is defined as follows:

⁶We consider an absolute number of citizens instead of a relative number of votes, as this simplifies expressions. This simplification can be made without loss of generality in our model, as the total number of citizens is fixed. In practice, the threshold would be defined to be a proportion of the number of citizens voting in favor of the higher growth rate relative to the total number of citizens. Moreover, we use the tie-breaking rule that if the number of citizens in favor of the higher growth rate is exactly M_k , the growth rate chosen by the voting process is the status quo.

Definition 2

According to Definition 1, a voting process with a fixed majority rule is characterized by $M_k = M$ for all $k \in \mathbb{N}$ and $N \geq M \geq \frac{N+1}{2}$.

This voting process is well-known and has already been examined by Bowen (1943). In our setting, we immediately obtain the following result:

Proposition 1

The issuance growth rate chosen by a voting process based on a fixed majority rule is g_L if $M \geq B$ and is an infinite issuance growth rate if $M < B$.

The proof of Proposition 1 is given in Appendix A. From this proposition, we directly observe that the first-best allocation is obtained if and only if $g_L = g_{FB}$ and $M \geq B$. An infinite growth rate with an associated hyperinflation yields minimal welfare, since the utility of savers goes to $-\infty$. Proposition 1 illustrates that fixed majority rules produce extreme outcomes, namely, either high money growth rates associated with high inflation or the lowest possible growth. We next define a voting process for a flexible majority rule:

Definition 3

According to Definition 1, a voting process with a flexible majority rule involves an increasing sequence $(M_k)_{k \in \mathbb{N}}$.

3 Results for Flexible Majority Rules

3.1 Implementing First-best Allocation

With the flexible majority rule, we immediately obtain the following result:

Proposition 2

The issuance growth rate under a flexible majority rule is

- (i) Infinite, if $\lim_{k \rightarrow +\infty} M_k < B$,
- (ii) g_L , if $M_1 \geq B$, and
- (iii) $k^* g_Z + g_L$ otherwise, where k^* fulfills $M_{k^*+1} \geq B > M_{k^*}$.

The proof of Proposition 2 is given in Appendix A. Note that the case (iii) includes the constellation where $\lim_{k \rightarrow +\infty} M_k = B$, which implies that M_k equals B at some point in time. From Proposition 2, we obtain

Proposition 3

Suppose that $g_{FB} > g_L$. The voting process based on a flexible majority rule with $M_k = \min\{k - 1, N\}$ for $k \in \mathbb{N}$ and $g_Z = \frac{g_{FB} - g_L}{B}$ yields the first-best allocation.

The proof of Proposition 3 is given in Appendix A.

We observe that a finely tailored flexible majority rule implements the socially optimal money growth rate. The reason is as follows: with the specified flexible majority rule, the growth rate corresponds to the socially optimal growth rate when the required size of the majority reaches the number of borrowers. This specified flexible majority rule adds the one more vote that is required for approval in each step and the growth rate is increased by $g_Z = \frac{g_{FB} - g_L}{B}$ in each step.

We note that in practice, we do not need to organize so many popular votes. If every citizen reveals his preferred money growth rate, this suffices to engineer the implementation of the first-best issuance growth rate in one step. Since citizens cannot gain anything by misrepresenting their preferences for issuance growth, such a communication stage would greatly simplify the voting process.

Proposition 3 allows to examine how the issuance growth rate implemented by the voting process is affected by a change in the citizens' utility functions and a change in the ratio $\frac{B}{S}$. When the citizens' utility functions change, we denote the resulting change of g_{FB} by $\Delta^u g_{FB}$. Moreover, a change in the ratio $\frac{B}{S}$ —where $N = B + S$ stays constant—induces a change in g_{FB} , which we denote by $\Delta^{\frac{B}{S}} g_{FB}$. We obtain:

Proposition 4

- (i) *Suppose the utility functions change, but Assumptions (1) and (2) still hold. Then, the issuance growth rate that is implemented by the voting process of Proposition 3 still equals g_{FB} and differs from the new first-best growth rate by $\Delta^u g_{FB}$.*
- (ii) *Suppose the ratio $\frac{B}{S}$ changes and induces a new first-best issuance growth rate $g_{FB} + \Delta^{\frac{B}{S}} g_{FB}$. Then, the deviation of the issuance growth rate implemented by the voting process in Proposition 3 from the new first-best growth rate is smaller than $\Delta^{\frac{B}{S}} g_{FB}$.*

The proof of Proposition 4 is given in Appendix A. Proposition 4 displays two important robustness properties. While changes in the composition of borrowers and savers entail a deviation between the implemented rate and the socially optimal rate, the deviation is bounded. Moreover, an increase in the number of borrowers yields more conservative money growth rates than is socially optimal.

3.2 Anticipating Flexible Majority Decisions

Of course, if a flexible majority rule is applied, agents who are signing financial contracts take into account how flexible majority rules will determine the growth rates of the currency and thus the inflation rates. To address this feedback effect, we consider the following two-stage setting:

Stage 1: Borrowers and savers sign financial contracts with a nominal interest rate i on the currency.

Stage 2: The society decides about the money growth rate g .

We assume that the Fisher equation $i = r + \pi^e$ holds, where $r > 0$ is the constant real interest rate and π^e is the expected inflation rate which is assumed to be equal to the expected growth rate of the currency g^e . With r known, the Fischer equation can be justified by arbitrage arguments. Under rational expectations, the expected growth rate equals the realized growth rate g , i.e. $\pi^e = g^e = g$.

We assume that agents face some cost of inflation. These costs can take several forms. For savers, this could simply represent the lack of complete hedging against inflation or the cost of hedging itself. Borrowers may face higher borrowing rates than saving rates. Using the derivation from Appendix B, the utility functions with anticipation of currency issuance decisions are given as follows:

$$\begin{aligned} U_B(g) &:= u \left(W - \frac{d(1 + r + g^e + \lambda_B g^e)}{1 + g^e} \right), \\ U_S(g) &:= u \left(\frac{s(1 + r + g^e - \lambda_S g^e)}{1 + g^e} \right), \end{aligned}$$

where r is the real interest rate, and λ_B and λ_S are the costs of inflation for borrowers and savers, respectively ($0 < \lambda_B, \lambda_S < 1$). We calculate the socially

optimal inflation under rational expectations $g^e = g$ and obtain

$$\begin{aligned} & Bu' \left(W - \frac{d(1+r+g(1+\lambda_B))}{1+g} \right) d(r-\lambda_B) \\ &= -Su' \left(\frac{s(1+r+g(1-\lambda_S))}{1+g} \right) s(r+\lambda_S). \end{aligned} \quad (4)$$

We note that (4) has a unique solution that depends on the cost of inflation and which we denote by $g_{FB}(\lambda_B, \lambda_S)$. Suppose now that we use the flexible majority rule according to Proposition 3 in Stage 2. Then, we obtain

Proposition 5

Using the flexible majority rule with $M_k = \min\{k-1, N\}$ for $k \in \mathbb{N}$ and $g_Z = \frac{g_{FB}(\lambda_B, \lambda_S) - g_L}{B}$ yields the first-best allocation under rational expectations.

The proof of Proposition 5 is given in Appendix A. Hence, if the citizens correctly anticipate the outcomes of flexible majority rules, the rule continues to implement the socially optimal inflation rate.

4 Discussion

In the next section, we provide a couple of simple numerical examples to explore how changes of the underlying parameters affect the working of the flexible majority rule. Second, if flexible majority rules are applied repeatedly, preferences may be less polarized. This happens if agents expect to be a borrower at one point in time and a saver at another point in time. Then, preferences may be single-peaked with a finite inflation vote as the most preferred vote for an individual. Flexible majority votes can be applied to such situations and an appropriate choice of the flexible majority rule can implement the first-best solution.⁷ Third, the concept of flexible majority rules can be applied to any other conflict situation. For cryptocurrencies, a main conflict regarding currency growth takes place between holders of the currency for store of value purposes and transaction verifiers who are rewarded with newly issued currencies. While the former are interested in low growth rates, the latter tend to favor higher rewards, which imply higher

⁷This can be proved by the procedure used in Section 3.

growth rates. Since both groups are interested in the expansion of the user base, the derived growth rate may not take polar values as for nominal currencies.

Fourth, we have focused on the design of a flexible majority vote for a given community. For cryptocurrencies, the community is evolving, and voting rights are not naturally granted as there is no one-person-one-vote requirement. Hence, new ways of assigning voting rights have to be developed.⁸ For instance, for proof-of-stake blockchains, voting rights may be simply be proportional to the stake individuals are holding. The flexible majority rule concept can readily be applied to such circumstances by weighting agents' utilities with the share of stakes the individuals hold. Of course, the influence of individuals with large stakes increases, since they can cast several votes in favor of proposals fostering their own objectives. This may raise concerns about manipulation, since several individuals with large stakes may be able to obtain control over the currency.

5 Numerical Examples

In this section, we provide a couple of simple and highly stylized examples to illustrate how the flexible majority rule works.

Example 1

In this example, we assume that $g_L = 0\%$, $u_B(g) = \ln(g + 1)$, $u_S(g) = -\alpha g^2$, $B = 3$, and $S = 2$, where $\alpha > 0$. We obtain from Equation (3)

$$g_{FB} = \sqrt{\frac{1}{4} + \frac{B}{2\alpha S}} - \frac{1}{2}.$$

We first investigate the impact of a change in citizens' utility, which we model by a change in α . In the base situation, we assume that $\alpha = 1$ and thus $g_{FB} = \frac{1}{2}\%$ and $g_Z = \frac{g_{FB} - g_L}{B} = \frac{1}{6}\%$. If α increases to 4, for example, and that the voting procedure and everything else remain the same, the issuance growth rate that is implemented by the voting procedure is still g_{FB} , which is different from the new first-best issuance growth rate $g_{FB} + \Delta^u g_{FB} = \frac{\sqrt{7}}{4} - \frac{1}{2}\%$. The deviation between the new first-best issuance growth rate and the issuance growth rate that

⁸If voting rights are issued on the basis of the number of accounts, individuals could inflate their voting rights by simply multiplying their accounts.

is implemented by the voting procedure is equal to $\Delta^u g_{FB} = \frac{\sqrt{7}}{4} - 1\% \approx -0.34\%$.

We now investigate the impact of a change in the ratio $\frac{B}{S}$, where $N = B + S$, $\alpha = 1$ and everything else remains constant. More specifically, we assume that the number of borrowers increases by 1 and we denote this increase by $\Delta = 1$. Thus, $B_{new} = B + \Delta = 4$ and $S_{new} = S - \Delta = 1$. In this example, the first-best issuance growth rate at the start is $g_{FB} = \frac{1}{2}\%$. If B increases to 4, S decreases to 1, and the voting procedure and everything else remain the same, the issuance growth rate that is implemented by the voting procedure is $\frac{B+\Delta}{B}(g_{FB} - g_L) + g_L = g_{FB} + \frac{\Delta}{B}(g_{FB} - g_L) \approx 0.67\%$, which is different from the new first-best issuance growth rate of 1% . The change of the first-best growth rate is $\Delta^{\frac{B}{S}} g_{FB} = 0.5\%$. The deviation between the new first-best issuance growth rate and the issuance growth rate that is implemented by the voting procedure is approximately equal to 0.33% and thus, less than $\Delta^{\frac{B}{S}} g_{FB} = 0.5\%$.

Example 2

In this example, we assume, as in Example 1, that the initial value of the growth rate g_L is given by $g_L = 0\%$ and the utility functions by $u_B(g) = \ln(g+1)$, $u_S(g) = -\alpha g^2$, where $\alpha > 0$. Furthermore, there are more savers than borrowers, i.e., $B = 5$ and $S = 8$. We again investigate the impact of a change in the citizens' utility by changing α . We first assume that $\alpha = 1$ and get $g_{FB} = \frac{1}{4}$ and $g_Z = \frac{1}{20}$. If α decreases to $\frac{1}{4}$, and if everything else remains the same, we should see a higher first-best issuance growth rate: Indeed, the new first-best issuance growth rate is given by $g_{FB} + \Delta^u g_{FB} = \frac{\sqrt{6}}{2} - \frac{1}{2}\% \approx 0.72\%$. The deviation between those two best issuance growth rates is equal to $\Delta^u g_{FB} = \frac{\sqrt{6}}{2} - \frac{3}{4}\% \approx 0.47\%$.

Looking at the impact of change in the ratio $\frac{B}{S}$ for $\alpha = 1$, we assume the following: We decrease the number of borrowers by 1 and increase the number of savers by 1, i.e. $B_{new} = 4$ and $S_{new} = 9$. At the beginning, the first-best issuance growth rate is $g_{FB} = \frac{1}{4}\%$. If B decreases to 4, and S increases to 9, and the voting procedure and everything else remain the same, the new implemented issuance growth rate is given by $\frac{B+\Delta B}{B}(g_{FB} - g_L) = 0.2\%$. This is different from $g_{FB} + \Delta^{\frac{B}{S}} g_{FB} = \frac{\sqrt{17}-3}{6}\% \approx 0.19\%$, which is the new first-best issuance growth rate. The deviation between the first-best issuance growth rate and the rate that is implemented by the voting procedure is small and approximately equal to 0.01% , and thus much less than $\Delta^{\frac{B}{S}} g_{FB} \approx 0.06\%$.

Example 3

The last example is characterized by $g_L = 0\%$ and the utility functions $u_B(g) = \ln(g + 1)$, $u_S(g) = -\alpha g^2$, where $\alpha > 0$. The amount of savers and borrowers is the same as in the numerical example 1, i.e., $B = 3$ and $S = 2$. Let $\alpha = 1$ and we obtain $g_{FB} = \frac{1}{2}\%$ and $g_Z = \frac{1}{6}\%$. If we change u_B to $u_B(g) = 4 \ln(g + 1)$, which is still a utility function fulfilling the requirements from Section 2, and if everything else remains the same, the new first-best issuance growth rate is given by $g_{FB} = \sqrt{\frac{1}{4} + \frac{2B}{\alpha S}} - \frac{1}{2} = \frac{\sqrt{13}}{2} - \frac{1}{2}$, i.e. $g_{FB} \approx 1.30\%$. The deviation between these two best issuance growth rates is equal to $\Delta^u g_{FB} \approx 0.8\%$.

When looking at the impact of change in the ratio $\frac{B}{S}$ for $u_B(g) = 4 \ln(g + 1)$, we obtain the following: We increase the number of borrowers by 1 and decrease the number of savers by 1, i.e. $B_{new} = 4$ and $S_{new} = 1$. At the start, the first-best issuance growth rate is $g_{FB} \approx 1.3\%$ and $g_Z \approx 0.43\%$. Assuming B_{new} and S_{new} , and if the voting procedure and everything else remain the same, the new implemented issuance growth rate is given by $\frac{B+\Delta B}{B}(g_{FB} - g_L) \approx 1.74\%$. This is different from $g_{FB} + \Delta^{\frac{B}{S}} g_{FB} = \frac{\sqrt{33}-1}{2} \approx 2.37\%$, which is the new first-best issuance growth rate. The error of the voting procedure is approximately equal to 0.63% , which is less than $\Delta^{\frac{B}{S}} g_{FB} \approx 1.07\%$.

6 Conclusion

We suggest that flexible majority rules are a promising avenue for issuance decisions of cryptocurrencies. Of course, our model is very simple and there are many further issues and extensions to be considered. First, as already discussed above, the number of borrowers and savers is endogenous and may itself react to expected inflation. Hence, more elaborated numerical examples can be considered to assess how much flexible majority rules depart from the welfare optimal solution when parameters change.

Second, one might consider additional ways to adapt flexible majority rules if circumstances change considerably. Again, flexible majority rules could be used to change specific parameters of the rule. Third, the impact of different growth rates on macroeconomic variables such as inflation and the real value of money is highly uncertain and subject to shocks of the currency demand. This makes

it harder for individuals to assess the impact of different money growth rates on their well-being.

Finally, one may doubt that large-scale voting processes can yield the desirable currency growth rates. Therefore, one should also investigate whether appropriately-designed committees representing the users of the currency—and using flexible majority rules—could take currency issuance decisions. Of course, this will necessitate an appropriate collective rule to elect the members for this committee.

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A Appendix – Proofs

Proof of Proposition 1.

If $M \geq B$, the result of the first popular vote is g_L . This is a result of the monotonicity property of the utility functions for B and S and sincere voting. B always prefers higher rates over lower ones. The opposite is true for S. Thus, the status quo is implemented. This means that the issuance growth rate g_L is chosen by the voting procedure. If $M < B$, the result of any popular vote $k \in \mathbb{N}$ is $kg_Z + g_L$. In this case, the voting process does not stop and the issuance growth rate chosen by the voting process is an infinite issuance growth rate by definition. \square

Proof of Proposition 2.

Suppose first that $\lim_{k \rightarrow +\infty} M_k < B$. In this case, $M_k < B$ for all $k \in \mathbb{N}$. Therefore, the result of any popular vote $k \in \mathbb{N}$ is $kg_Z + g_L$. In this case, the voting process does not stop and the issuance growth rate chosen by the voting process is by definition an infinite issuance growth rate.

Suppose now that $M_1 \geq B$. In this case, the result of the first popular vote is g_L , which is the status quo. This means that this issuance growth rate g_L is chosen by the voting procedure.

Suppose now that there is $k \in \mathbb{N}$ such that $M_{k+1} \geq B > M_k$. In this case, all popular voting rounds $h \leq k$ are such that $M_h < B$ and thus, $(k+1)g_Z + g_L$ is the issuance growth rate chosen during the popular voting round k . In the popular voting round $k+1$, $(k+1)g_Z + g_L$ is rejected against the status quo from the last round, as $M_{k+1} \geq B$. \square

Proof of Proposition 3.

Suppose that the voting process is based on a flexible majority rule, with $M_k = \min\{k-1, N\}$ for $k \in \mathbb{N}$ and $g_Z = \frac{g_{FB} - g_L}{B}$. Then, for $k = B+1$ we have that $M_{B+1} = B > B-1 = M_B$ and the result of the voting process is thus given by $Bg_Z + g_L = g_{FB}$. \square

Proof of Proposition 4.

If the citizens' utility functions change, the first-best growth rate becomes $g_{FB} + \Delta^u g_{FB}$. However, everything else stays equal and the issuance growth rate implemented by the voting procedure in Proposition 3 is g_{FB} .

Without loss of generality, we now assume that the ratio $\frac{B}{S}$ increases. In this case, Equation (3) shows that g_{FB} has to increase as well, as $-\frac{u'_S(g)}{u'_B(g)}$ is an increasing function of g . This change is denoted by $\Delta^{\frac{B}{S}}g_{FB}$. The growth rate implemented by the voting procedure of Proposition 3 is given by $\frac{B+\Delta B}{B}(g_{FB} - g_L) + g_L = g_{FB} + \frac{\Delta B}{B}(g_{FB} - g_L)$ and the new first-best issuance growth rate is given by $g_{FB} + \Delta^{\frac{B}{S}}g_{FB}$. The deviation is thus $\Delta^{\frac{B}{S}}g_{FB} - \frac{\Delta B}{B}(g_{FB} - g_L) < \Delta^{\frac{B}{S}}g_{FB}$. \square

Proof of Proposition 5.

Suppose that agents have formed some expectation g^e in Stage 1. Since the utility for borrowers (savers) continues to be strictly increasing (decreasing) in g for any given inflation expectation, the voting behavior remains polar: savers reject inflation rates higher than g_L and borrowers favor higher inflation rates over lower ones. Hence, we can apply the reasoning in the proof of Proposition 3 and conclude that the flexible majority rule implements $g_{FB}(\lambda_B, \lambda_S)$. Rational expectation then imposes $g^e = g_{FB}(\lambda_B, \lambda_S)$. \square

B Rationale for the Limit Conditions of Utility Functions

Both conditions

$$\begin{aligned} \lim_{g \rightarrow +\infty} u'_B(g) &= 0 \quad \text{for citizens } i = 1, \dots, B, \text{ and} \\ \lim_{g \rightarrow +\infty} u'_S(g) &= -\infty \quad \text{for citizens } i = B + 1, \dots, N \end{aligned}$$

can be justified in a framework in which borrowers and savers enter financial contracts first and inflation is realized later. Suppose that borrowers and savers have the following utility functions:

$$\begin{aligned} u_B(g) &:= u\left(W - \frac{d}{(1+g)p_w}\right), \\ u_S(g) &:= u\left(\frac{s}{(1+g)p_w}\right), \quad \text{respectively,} \end{aligned}$$

where W represents the borrowers' real wealth, p_w the price of a consumption bundle, d represents borrowers' net debt with a contractually fixed nominal interest rate payment on the debt, s denotes savers' net nominal savings including a fixed nominal interest rate payment, and u is a strictly increasing and strictly concave utility function.⁹ The following condition, which is a stronger condition than the Inada Condition,

$$\lim_{w \rightarrow +\infty} \frac{u'(\frac{1}{w})}{w^2} = +\infty$$

implies for savers that

$$\lim_{g \rightarrow +\infty} u'_S(g) = \lim_{g \rightarrow +\infty} -\frac{s}{(1+g)^2 p_w} u'\left(\frac{s}{(1+g)p_w}\right) = -\infty.$$

Moreover, we obtain for borrowers that

$$\lim_{g \rightarrow +\infty} u'_B(g) = \lim_{g \rightarrow +\infty} \frac{d}{(1+g)^2 p_w} u'\left(W - \frac{d}{(1+g)p_w}\right) = 0.$$

⁹To ensure that $u_S(g)$ is concave in g , the degree of concavity of u has to be sufficiently strong, i.e., $\frac{u''(\cdot)}{u'(\cdot)} > \frac{p_w(1+g)}{s}$.

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