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Democratic (crypto-)currency issuance

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Abstract
Can democratic currency issuance lead to welfare-optimal results/stable currency values? We explore (crypto-)currency issuance with flexible majority rules. With flexible majority rules, the vote-share needed to approve a particular currency issuance growth is increasing with this growth rate. By choosing suitable flexible majority rules, socially optimal growth rates can be achieved in simple settings. By adding a communication stage, in which agents can reveal their preferences for currency growth, the voting process can be ended in three rounds. With other procedures, one could even obtain the first-best solution in one voting round. 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

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

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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 expansion[1] 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—in the sense that all currency holders participate in collective decisions—about the growth rate of the currency in each period.

In this paper, we explore the third option; democratically-governed currency issuance. An example of such a democratically-governed crypto currency is Tezos (Goodman, 2014). Typically, participants in the blockchain have different 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 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.

A similar situation with heterogeneous preferences regarding the growth rate can also be found outside the cryptocurrency domain. For instance, monetary policy decisions for the ECB are taken in the ECB council's meeting and by a collective decision. It is well-known that preferences of council members regarding the tightness of monetary policy differ and can be quite polarized (see e.g. Gersbach and Hahn 2009). For such bodies, it is also the question which collective decision rule they should use to decide about monetary policy.

The key issue 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

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

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 yield currency growth rates which are optimal from a utilitarian perspective? In this paper, we suggest that appropriately-designed flexible majority rules may achieve this objective.

We use a simple model with deep conflicts among the 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 substantially.

We take the saver/borrower conflict as a leading example. However, the construction can be applied to other conflicts, as we will discuss in Sect. 6. 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 issuance.[2] 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 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 issuance[3] and argue that it can constitute an efficient democratic decision-making rule for the issuance of a currency. With flexible majority rules, the vote-share needed to approve a particular currency issuance growth is increasing with 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.

We introduce two voting processes for the application of flexible majority rules. First, we consider a sequential process in which the proposed growth rate is increased step-wise. Then, the growth rate selected in a given step is implemented when the growth rate proposed as next step is rejected. Second, we add a communication stage in which agents first reveal their preference for currency growth. There exists a perfect Bayesian Nash equilibrium in which individuals will truthfully reveal their preferences and the voting process can already start at a suitable growth rate.

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

[3] See Gersbach (2017a, 2017b) for a survey of flexible majority rules.

Moreover, it will only require three voting rounds to determine the socially optimal currency growth. Finally, we show that optimal money growth rates are realized if agents entering financial contracts anticipate the ensuing inflation rates determined by these flexible majority rules.

The results on flexible rules also open up insights as to whether flexible majority rules lead to stable currency values. This is addressed in Sect. 6.

In this short paper, several issues cannot be addressed, such as the microfoundation of currency demand and dynamic extensions of the model. Moreover, 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 work and we refer to Camera (2017), as well as Berentsen and Schär (2018) for a comprehensive evaluation of the potential and limitations of cryptocurrencies and digital currencies.

The paper is organized as follows. Our model is described in Sect. 2, where we also provide the results for fixed majority rules. In Sect. 3, we provide the results for flexible majority rules. In Sect. 4, we show that with a suitable communication stage, the number of voting rounds needed is three at most. In Sect. 5, we present some simple numerical examples. In Sect. 6, we discuss ways to apply flexible majority rules. Section 7 concludes.

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 the de facto power to take currency issuance decisions. For currencies, the citizenry could be defined as the set of all currency holders or currency borrowers. For simplicity, we assume that N is an odd number.[4] There are B (net) borrowers ($N > B > 0$), and $N - B$ (net) savers. We denote the number of net savers by $S := N - B$. Except for Sect. 4, 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 that citizens $i = 1, \ldots, B$ are borrowers and citizens $i = B + 1, \ldots, N$ are savers. Agents have utility functions over the growth rate of currency. We assume that a borrower $i = 1, \ldots, B$ has a utility function $u_B : \mathbb{R}_{+0} \to \mathbb{R}$ that is twice continuously differentiable, strictly increasing, and strictly concave, and which satisfies

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

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

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[4] When N is even, one has to add the case where there is a tie.

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

We provide a rationale for the two limit Conditions (1) and (2) in Appendix B. The utility assumptions imply that borrowers prefer higher growth rates to 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 $\lim_{g\to+\infty} U'(g) = -\infty$. Hence, $U(g)$ has a unique non-negative global maximizer, which is either zero or a solution of the following equation:

$$Bu'_B(g) = -Su'_S(g). \tag{3}$$

We use g_{FB} to denote maximizer of $u(g)$, and this is called 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 Eq. (3), it is straightforward to show that in this example, the welfare optimal (or first-best) level of issuance growth rate is given by

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

In Fig. 1, we display the first-best growth rate as a function of the ratio of borrowers and savers.
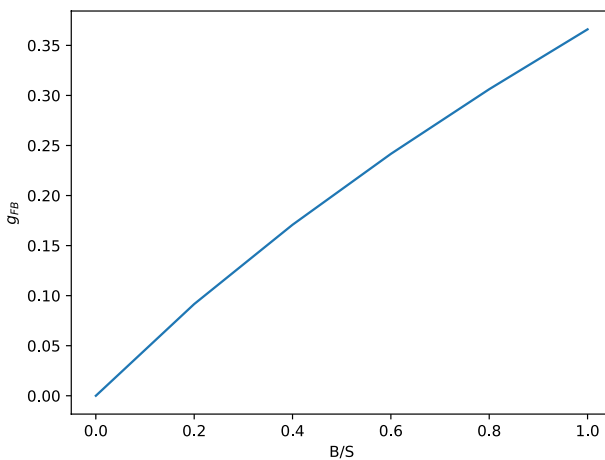

Fig. 1 The first-best growth rate as a function of the ratio of borrowers and savers given by Eq. (4) with $\alpha = 1$

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 principle 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 principle 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 Sect. 2.2.1, we give more formal details about the functioning of these voting processes, and in Sect. 2.2.2, we examine their performance.

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. 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 that is fixed. 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 the 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 non-decreasing sequence of integer thresholds $(M_k)_{k \in \mathbb{N}}$, s.t. $M_k \leq N, \forall k \in \mathbb{N}$, where N is the number of citizens, defined iteratively in the following way. During the kth popular vote, where $k \in \mathbb{N} = \{1, 2, \ldots\}$, 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 vote $k+1$ if and only if at least a number M_k of citizens votes in its favor.[6] If this is not the case, the voting process stops and the issuance growth rate that is chosen by this voting process is $g_L + (k-1)g_Z$.
- 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.

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[6] We 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 as a proportion of the number of citizens voting in favor of the higher growth rate relative to the total number of citizens.

Throughout the paper, we look for perfect Bayesian equilibria and assume that citizens eliminate weakly dominated strategies.[7] Since citizens have polar preferences, i.e. they either support a zero growth rate or arbitrarily high money growth rates, all citizens vote sincerely. We now define the voting processes based on fixed and flexible majority rules and examine their performance.

2.2.2 Majority rules

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

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 $M > B$ and is an infinite issuance growth rate if $M \leq B$.*

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 $M > B$. 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 A voting process with a flexible majority rule is a voting process according to Definition 1, involving an increasing sequence $(M_k)_{k \in \mathbb{N}}$, and is strictly increasing for at least one $k \in \mathbb{N}$.

This means that in each new stage, a larger majority is needed to implement the proposal. In other words, a larger growth rate needs the support of a larger number of citizens. Because agents vote sincerely, borrowers vote *Yes* and savers vote *No* at any stage of the voting process.

3 Results for flexible majority rules

3.1 Implementing first-best allocation

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

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[7] Otherwise, a multiplicity of equilibria—including quite implausible ones—could be supported.

Proposition 2 *The issuance growth rate under a flexible majority rule is*
  (i) *infinite, if* $\lim_{k \to +\infty} M_k \leq B$,
  (ii) g_L, *if* $M_1 > B$, *and*
  (iii) $k^* g_Z + g_L$ *otherwise, where* k^* *fulfills* $M_{k^*+1} > B \geq M_{k^*}$.

The proof of Proposition 2 is given in Appendix A. The Proposition states that if the vote threshold is lower than the number of borrowers in all voting stages, an infinite growth rate will be chosen. If, on the other hand, the threshold is always higher than the number of borrowers, the growth rate will remain at the status quo. In the third case, the threshold is set in such a way that the optimal growth rate is implemented. From Proposition 2, we obtain

Proposition 3 *Suppose that* $g_{FB} > g_L$. *The voting process based on the flexible majority rule with* $M_k = \min\{k, N\}$ *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 suitable 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 until $M_k = B$.

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.

The nominal interest rate i is given by $i = r + \pi^e$, 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 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. These costs could simply consist in the impossibility of *complete* hedging against inflation or the *cost* of hedging. Borrowers may face borrowing rates which are higher than saving rates. Using the derivation from Appendix B, the

utility functions $u_B(g)$ and $u_S(g)$ with anticipation of currency issuance decisions are given as follows:

$$u_B(g^e) := u\left(W - \frac{d(1 + r + g^e + \lambda_B g^e)}{1 + g^e}\right),$$

$$u_S(g^e) := u\left(\frac{s(1 + r + g^e - \lambda_S g^e)}{1 + g^e}\right),$$

where r is the real interest rate, W represents the borrowers' real wealth, and λ_B and λ_S are the costs of inflation for borrowers and savers, respectively ($0 < \lambda_B, \lambda_S < 1$) and the utility function u is further characterized in Appendix B. Furthermore, d and s are the borrowers' net debt and the savers' net savings, respectively. We calculate the socially optimal inflation under rational expectations $g^e = g$, using Eq. (3), and obtain

$$\begin{aligned} & Bu'\left(W - \frac{d(1 + r + g(1 + \lambda_B))}{1 + g}\right)d(r - \lambda_B) \\ & = Su'\left(\frac{s(1 + r + g(1 - \lambda_S))}{1 + g}\right)s(r + \lambda_S). \end{aligned} \tag{5}$$

We note that Eq. (5) has a unique solution, due to the properties of the utility function. The solution depends on the cost of inflation, which we denote by $g_{FB}(\lambda_B, \lambda_S)$. Suppose now that we use the flexible majority rule presented in Proposition 3 in Stage 2. Then, we obtain

Proposition 4 *Using the flexible majority rule, with $M_k = \min\{k, N\}$ 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 4 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.

3.3 Revisions

Since economic circumstances can change, as well as the ratio between borrowers and savers, it is useful to repeat the determination of the growth rate periodically, since the implemented growth rate might no longer be optimal. Importantly, when the voting is repeated, the process always has to start with the initial value g_L. In this way, the optimal growth rate is chosen.

4 Communication and simple voting processes

4.1 A three-round voting proposal

We next show that in practice, we do not need to organize so many popular votes. If every citizen can reveal his preferred money growth rate, this suffices to engineer the implementation of the first-best issuance growth rate with a few voting rounds. However, we have to ensure that individuals do not want to misrepresent their preferences.

We therefore add a communication stage before voting takes place. At the communication stage, individuals reveal their preferred growth rate, or equivalently, reveal whether they are a borrower or a saver. We stress that communication happens only once, so that agents cannot revise their preferred growth rate announcement.

To examine the consequences, we use the function $g_{FB}(B)$ given by Eq. (4) that yields the first-best growth rate if B borrowers and $N - B$ savers are actually present. The communication and voting process now looks as follows:

1. At the communication stage, every agent has the chance to signal his preferred growth rate, or equivalently, to send a message indicating whether he is a borrower or a saver. The message may not be truthful. The number of agents who claim to be borrowers is denoted by $\hat{B}$.
2. Based on the communicated number of borrowers, the first growth rate is determined as $g_{FB}(\max\{\hat{B} - 1, 0\})$, with the required majority $M_1 = \max\{\hat{B} - 1, 0\}$. All agents vote on this proposal.
3. If the threshold is reached, the next proposal is $g_{FB}(\hat{B})$ with $M_2 = \hat{B}$. Otherwise, g_L is implemented.
4. If the threshold is reached, the next proposal is $g_{FB}(\hat{B} + 1)$, with majority threshold $M_3 = \hat{B} + 1$. All agents vote on this proposal.
5. In the k−th voting round, $k \geq 1$, the growth rate on the table is $g_{FB}(\hat{B} + k - 2)$ and the threshold is $M_k = \hat{B} + k - 2$.
6. The process continues until the threshold is no longer reached. Then the last proposal that reached the required majority is implemented.

We look for perfect Bayesian Nash equilibria (henceforth simply *equilibria*) and obtain

Proposition 5 *In the above communication and voting procedure, there exists an equilibrium in which no agent has an incentive to misrepresent his preferences. The first-best growth rate is implemented in this equilibrium, with three voting rounds.*

The proof of Proposition 5 is given in the Appendix A. The preceding proposition shows that attempts to misrepresent the preference, in order to induce a rejection of the first vote and the implementation of g_L, can be avoided by choosing a suitable starting point $g_{FB}(\max\{\hat{B} - 1, 0\})$ of the voting process.

We next discuss whether other equilibria might exist, in which not all agents reveal their preferences truthfully. Let us assume that several—or all—borrowers misrepresent their preferences, but savers represent their type truthfully. Then, the initial growth rate $g_{FB}(\max\{\hat{B}-1,0\})$ would be lower than $g_{FB}(B)$. But since voting is sincere, the voting process would end with $g_{FB}(B)$. It would simply take more than three voting rounds. Suppose that several—or all—savers misrepresent their preferences, but borrowers represent their type truthfully. Then, the first growth rate on which there is a vote, $g_{FB}(\hat{B})$, would be larger than $g_{FB}(B)$, since the growth rate would not reach the threshold because all agents vote sincerely. Hence, g_L would be implemented, and thus, manipulation by a group of savers would be profitable. To sum up, manipulation incentives by coalition of savers exist and thus, the equilibrium presented in Proposition 5 is not stable against coalition deviations.

We also note that abstention is weakly dominated by participating in voting, as every individual is pivotal in the last voting stage in the equilibrium in Proposition 5.

An important remark is in order. If the rejection of $g_{FB}(\max[\hat{B}-1,0])$ led to $g_{FB}(\max[\hat{B}-1,0])$ itself, one could avoid such manipulation attempts by savers. Moreover, one could even achieve the desired outcome by directly proposing $g_{FB}(\hat{B})$ in the first round, and if this proposal did not reach the necessary threshold, $g_{FB}(\hat{B})$ would be implemented. With such procedures, we would even obtain the desired result in one round. However, such procedures rely on the property that the rejection of a proposal leads to the implementation of that same proposal, which is an undesirable feature. The rejection of a proposal should lead to the approval of a previously-supported proposal or to the status quo solution g_L if there is no previously-supported proposal.

4.2 Impossibility of two voting rounds

In the previous subsection, we showed how a three-round voting procedure will implement the first-best solution as a perfect Bayesian Nash equilibrium if the voting process is preceded by a communication stage. Now, we show why the first-best solution cannot be implemented in less than three voting rounds with the procedure outlined in the last subsection.

At the communication stage, savers and borrowers can signal their type (truthfully or not). Suppose that no one misrepresents preferences. Then, one can achieve the first-best solution with two rounds: The proposal is $g_{FB}(B)$ and the threshold then is $M_1 = B$. In a first round, agents vote on the proposal $g_{FB}(B)$. If the threshold M_1 is reached, the next proposal is $g_{FB}(B+1)$, with majority threshold $B+1$. Since the threshold is not reached in the second round, the proposal $g_{FB}(B)$ is implemented. However, this procedure can be manipulated. Suppose for instance, that instead, $\hat{B} = B+1$ is revealed, since one saver signals that he is a borrower. The voting proposal is then $g_{FB}(B+1)$ and the threshold $M_1 = B+1$. Since there are only B borrowers, the threshold is not reached, the proposal is rejected, and g_L is implemented. This is preferred by the savers, so that manipulation is beneficial. Therefore, trying to limit voting to two rounds,

preceded by a communication stage where the first-best solution is directly proposed, does not guarantee that the first-best rate is implemented.

5 Numerical examples

In this section, we provide a couple of simple and highly stylized examples to illustrate how the flexible majority rule characterized in Proposition 4 works and how outcomes change when the voting rule is kept fixed, but the number of borrowers and savers changes.

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 Eq. (3),

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

We assume $\alpha = 1$. Then, in the base situation, the first-best issuance growth rate is $g_{FB} = \frac{1}{2}\%$. We next investigate the impact of a change in the ratio $\frac{B}{S}$. 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 $S_{new} = S - \Delta = 1$. If B increases to 4, S decreases to 1, but all other parameters 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 in the first-best growth rate is denoted by $\Delta^{\frac{B}{S}} g_{FB}$ and equal to 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 assume that $\alpha = 1$ and obtain $g_{FB} = \frac{1}{4}$ and $g_Z = \frac{1}{20}$.

If B decreases to 4 and S increases to 9, and the voting procedure and everything else remain the same, the new issuance growth rate that is implemented is given by $\frac{B+\Delta}{B}(g_{FB} - g_L) = 0.2\%$, where $\Delta = 1$. This is different from $\frac{\sqrt{17}-3}{6}\% \approx 0.19\%$, 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, approximately equal to 0.01%, and thus much less than $\Delta^{\frac{B}{S}} g_{FB} \approx 0.06\%$.

6 Discussion

In the previous section, we provided a couple of simple numerical examples to examine how changes of the underlying parameters affect the working of the flexible majority rule. Several further issues have to be addressed. First, 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 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.[8]

Second, the concept of flexible majority rules can be applied to any other conflict situation. For cryptocurrencies, a main conflict regarding currency growth can take place between individuals who hold 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 growth rates. Since the two groups are interested in the expansion of the user base, as this increases the value of the currency, the desired growth rate may not take polar values.

Third, the former observation also leads to insights as to how optimally-chosen flexible majority rules may foster stability of a currency whose issuance is determined by such a rule. As long as the group of transaction verifiers is a minority—and remains comparably small, but not too small, the growth rate of the currency will be comparatively small. If the expansion of the user base—and thus cryptocurrency demand—is also slow, this would guarantee a stable currency value. Pursuing this line of argument further suggests that the cryptocurrencies in which the share of transaction verifiers is in a certain range, compared to the cryptocurrency holders as a whole, flexible majority rules on cryptocurrency issuance have the best chance to produce a stable currency value. This will be an important topic for further research.

Fourth, we have focused on the design of a flexible majority vote for a given community. There are no constraints on the size of the community, as flexible majority rules can be applied to any community size. For cryptocurrencies, however, the community is evolving, and voting rights are not automatically granted, as there is no one-person-one-vote requirement. Hence, new ways of assigning voting rights have to be developed.[9] For proof-of-stake blockchains, for instance, voting rights may simply be proportional to the stakes that 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

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[8] This can be proven by the procedure used in Sect. 3.

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

manipulation, as several individuals with large stakes may obtain control over the currency.

7 Conclusion

We suggest that flexible majority rules are a promising avenue for issuance decisions of (crypto-)currencies. Of course, our model is very simple and many further issues have to be considered. First, how can optimal growth rates be determined for an entire class of utility functions that satisfy our conditions—or more general conditions? Second, as already discussed above, the number of borrowers and savers is endogenous and may itself react to expected inflation. Hence, how frequently flexible majority rules should be revised is an important issue for future research.

Third, one might consider ways to use flexible majority rules to change specific parameters of the flexible rule itself. Fourth, the impact of different growth rates on macroeconomic variables such as inflation and on 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. While flexible majority rules can also be applied in such circumstances, how to construct flexible majority rules that are sufficiently robust against such uncertainties is an open issue.

Fifth, other interesting voting rules may be useful for currency issuance decisions in dynamic settings when voting decisions across periods may be linked, such as the Borda or Pluri–Borda rule (Nehring, 2018) or Qualitative Voting (Hortala-Vallve, 2012).

Finally, one may doubt that large-scale voting processes can yield the desirable currency growth rates, as, e.g., the turnout may be low. 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 require an appropriate collective rule to elect the members for this committee.

A. Appendix—Proofs

Proof of Proposition 1 If $M > B$, 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 $M \leq B$, 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. □

Proof of Proposition 2 Suppose first that $\lim_{k \to +\infty} M_k \leq B$. In this case, $M_k \leq B$ 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 $M_1 > B$ (and thus $M_k > B$ for all $k \in \mathbb{N}$). 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 a $k \in \mathbb{N}$, such that $M_{k+1} > B \geq M_k$. In this case, all popular voting rounds $h \leq k$ are such that $M_h \leq B$ and thus, $kg_Z + g_L$ 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 $M_{k+1} > B$ and savers prefer lower growth rates. □

Proof of Proposition 3 Suppose that the voting process is based on a flexible majority rule, with $M_k = \min\{k, N\}$ for $k \in \mathbb{N}$ and $g_Z = \frac{g_{FB} - g_L}{B}$. Then, for $k = B + 1$ we have that $M_{B+1} = B + 1 > B = M_B$ and with $k^* = B$, using Proposition 2, the result of the voting process is thus given by $Bg_Z + g_L = g_{FB}$. □

Proof of Proposition 4 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 $g^e = g_{FB}(\lambda_B, \lambda_S)$. □

Proof of Proposition 5 Suppose first that all individuals reveal their preferences truthfully, i.e. they reveal whether they are borrowers or savers, and thus, $\hat{B} = B$ is revealed. Then, with the same logic as in Proposition 2, the voting process starts with $g_{FB}(B - 1)$, which will be adopted, moves to $g_{FB}(B)$, which is also adopted, and ends with the rejection of $g_{FB}(B + 1)$. Hence $g_{FB}(B)$ is implemented in three steps.

Suppose second that one individual misrepresents his preferences. Suppose that $\hat{B} = B + 1$ is revealed. Then the voting process starts with $g_{FB}(\hat{B} - 1) = g_{FB}(B)$, which will be adopted, since $\hat{B} - 1 = B$ individuals are needed for its support. At the next voting stage, $g_{FB}(B + 1)$ will be rejected, since only B individuals will support this proposal. Hence, $g_{FB}(B)$ will be implemented.

Suppose finally that $\hat{B} = B - 1$ is revealed. Then, the voting process starts with $g_{FB}(B - 2)$, proceeds to $g_{FB}(B - 1)$, $g_{FB}(B)$, and $g_{FB}(B + 1)$. The last proposal will be rejected and $g_{FB}(B)$ will be implemented.

To sum up, misrepresenting of preferences by one individual will affect the number of voting rounds, but g_{FB} will be selected in all cases.[10] □

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[10] To counteract the coordination of a set of individuals of size k ($k \in \mathbb{N}_+$) to misrepresent their preferences, one can also start with a lower value, i.e. $g_{FB}(\hat{B} - k)$ with $k > 1$.

B. Rationale for the limit conditions of utility functions

The two conditions

$$\lim_{g\to+\infty} u'_B(g) = 0 \qquad \text{for citizens } i = 1, \dots, B, \text{ and}$$

$$\lim_{g\to+\infty} u'_S(g) = -\infty \qquad \text{for citizens } i = B+1, \dots, N$$

are sufficient conditions to obtain a unique solution when we maximize the utilitarian social welfare function. Of course, in some examples, milder conditions will suffice to generate unique solutions.

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

$$u_B(g) := u\left(W - \frac{d}{(1+g)p_w}\right),$$

$$u_S(g) := u\left(\frac{s}{(1+g)p_w}\right), \quad \text{respectively,}$$

where W represents the borrowers' real wealth, p_w represents the price of a consumption bundle, d represents the borrowers' net debt with a contractually fixed nominal interest rate payment on the debt, s denotes the savers' net nominal savings including a fixed nominal interest rate payment, and u is a strictly increasing and strictly concave utility function.[11] The following condition, which is a stronger condition than the Inada Condition,

$$\lim_{w\to+\infty} \frac{u'\left(\frac{1}{w}\right)}{w^2} = +\infty,$$

with $w = \frac{(1+g)p_w}{s}$, implies for savers that

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

An example is $u(w) = \frac{1}{w^2}$. Moreover, we obtain without any further assumption that for borrowers,

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

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[11] To ensure that $u_S(g)$ is concave in g, the degree of concavity of u has to be sufficiently strong, i.e., $\frac{-u''(\cdot)}{u'(\cdot)} > \frac{2p_w(1+g)}{s}$.

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