Chapter 1
The DECENT Software Modeling Toolkit to Design Decentralized Governance Models

Fadime Kaya, Yulu Wang, Jaap Heringa and Jaap Gordijn

Abstract Many companies and even certain governments strive for centrally led systems. At first hand, this might look beneficial, but as it can easily result in value extraction, this is not in the interest of society. Rather than fining and giving financial penalties to the well-known centralized platforms for taking monopolistic positions, a better approach is to encourage and support developing viable and equitable alternatives, organized as decentralized digital ecosystems in which decision power is distributed. Blockchain technology can play an enabling role here, but there is work to do. First, blockchain systems should provide rich support for decentralized on-chain governance. Second, the expression of governance structures should be closer to the end-users, rather than requiring in-depth knowledge about distributed systems programming. Third, high-level graphical modeling languages can help here, provided that automated translation of models in these languages to smart contracts is supported. We position and introduce the DECENT software modeling toolkit for designing decentralized governance. This allows for designing, analyzing and exploring decentralized governance for digital ecosystems. We explain the design notations of DECENT and use the toolkit to experiment with the case of the Digital Euro.

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1.1 Introduction

From a societal perspective, decentralization is a response to design digital ecosystems in which (1) value extraction is prevented, (2) transparency is achieved, and (3) decision making in terms of formulation, monitoring and executing are governed decentralized. In a decentralized design approach there is more than one party in both the operating ecosystem (producing the actual economic value), as well as in governing the digital ecosystem. We position this as *decentralized governance*, in which the rules of monitoring, decision making and execution are decentralized over multiple parties. If decentralized governance should serve as an alternative for the centralized digital ecosystems, governance should not only be defined in terms of parties, rules (and legislation), incentives, decision-making procedures, but more importantly, should also be supported by technology, to cope with the fast-evolving internet-enabling centralized competitors.

Even though we consider blockchain technology as a tool to support decentralized governance, we argue that with respect to decentralized governance, most blockchain technologies are only in their preliminary phase. To become really useful, decentralized digital ecosystems should ideally support on-chain governance that is comprehensible and transparent to all parties involved. We consider governance as a topic of design: there is a clear need for software tooling and a modeling language that can contribute in designing decentralized digital ecosystems. Thus, a model-based design is an effective approach to manage and design these complex digital ecosystems. To provide scholars and digital ecosystems designers with an intuitive model-based approach of decentralized governance we propose the DECENT [1] software modeling toolkit, which is a model-based design approach, underpinned with the DECENT meta model, graphical notation and implemented as software tooling in ADOxx. This allows for design, analysis, and evaluation of governance models for digital ecosystems. We assess the usability of the DECENT software modeling toolkit with the industry case of the Digital Euro. To remove centralized financial parties in the payment infrastructure of Europe, the European Commission (EC) proposes the Digital Euro, and it will be likely implemented in the euro-currency zone in the year of 2027. Currently the financial payment infrastructure in Europe is dominated by Big Tech companies. Naturally, this raises governance questions and concerns for the financial stability and security of the payment structures in eurozone (EZ) for the foreseeable future.

1.2 Research Approach

In our research we position decentralized governance as a design problem as we want to express the relevant governance artifacts in terms of models. As with any design problem, an important question is which artifacts are required to express design decisions, and more importantly how to represent and conceptualize them. In order to facilitate digital asset and ecosystem design in which decision making is decentralized we propose DECENT [1] a model-based approach that allows for designing, describing and analyzing governance models. Our problem statement is how decentralized governance can be structured and designed within a real world environment, and we want to express this in terms of models (see e.g. [2]). A semi-formal specification as a model facilitates for a better and shared understanding of the domain.

We have a well-defined set of the meta model semantics that we can draw upon [3]. By taking the meta model as a baseline, we develop the DECENT graphical notation. This graphical notation is implemented as the DECENT software modeling toolkit which allows to create and design DECENT governance models. We follow the principles of rapid prototyping [4], as it allows us efficiently change and revise the visualization, this approach contributes to shape, observe and study the phenomena of decentralized governance within a software environment. The technology we use to develop a graphical notation (which follows the meta model semantics), is a meta case software tooling platform: ADOxx [5]. The assessment of the graphical notation and governance models will be of discussion with the case of Digital Euro. In earlier work [6] we experimented using existing techniques to represent governance models, we are conclusive that it does not fulfill our design requirements for decentralized governance design. Therefore, we develop the DECENT graphical notation with corresponding software tooling to support a model-based approach of decentralized governance design. This is presented as the DECENT Software Modeling Toolkit. This leads to our main research question:
How can decentralized governance be conceptualized by a graphical notation and supported by software tooling?

1.3 Notation Design Requirements

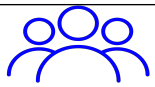
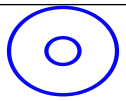
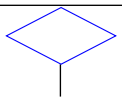
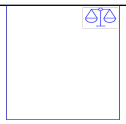
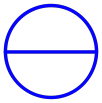
For the graphical notation we present the following design criteria as inspired by [7, 8]. The main design goal is as we formulated before, a light-weight tractable notation with a limited number of concepts and relations, such that it can easily be explained to practitioners. A minimized notation cf. Occam's razor, is an important *feature* of the graphical notation.

1. **Semantic Mapping.**
   We follow the meta model semantics to a certain extent. We make the remark here that we will reduce the amount of relationships in the notation to construct governance models. Next to that we will also combine some meta model concepts in the graphical notation. This allows us to simply the notation and makes it easier to explain, learn and to apply.

2. **Intuitive**.
   It should be designed in such an approach, that in principle no computing knowledge is required by the end-user, as the graphical notation should be applied intuitively. Graphical notations should be logical and connected to the real-world application. The notation and interpretation should be directly deductible from the used visual constructs, and known universally as a logical symbol. Too much symbols within a model do not contribute in understanding and explaining the model. As such complexity should be avoided, and notations should be combined. We take semantic perversity into account when designing graphical notations [9].

3. **Decentralization.**
   When constructing the models, we consider the following model distinctions that infer decentralization. The first model is the representation of the governance constructs: objective, goal, legislation, regulation, rule set, rules, mechanism, policy, incentive, reward and penalty. We refer to this model as the governance construct and the role a party plays should be made directly visible. For example, group and actor use their associated role [Define, Monitor, Execute] in the decision making procedure to modify the governance construct. Decision making also contains the vote attribute, which form together with the governance construct the semantics of the decentralized graphical notation.

Table 1.1: DECENT Graphical Notation

DECENT Concept	Graphical Notation	Description
Actor		An independent entity represented by the icon of a person.
Group		A group is a collection of entities that share one or more characteristics, represented by the icon concatenation of multiple persons.
Goal-Objective		Consists of two circles, as the inner circle represents a goal and the outer circle represents objective.
Decision making		Decision making used by a party to take a decision, this occurs via the construction of vote, represented as a diamond upper right.
Vote		Vote is part of decision making and represented as a diamond-line.
Rule Set		Rule Set consists of legislation, regulation and rules, represented as a rectangle boundary. Rule Set is about fairness, hence the scale of justice upper right.
Incentive		Penalty & reward as a graphical segmentation in a circle acting as two opposites, which form together the semantics of incentive.
Policy-Mechanism		A policy is a document represented as the icon file explorer. Mechanism is part of policy and implements the policy, represented by the icon engine.

1.4 DECENT Software Modeling Toolkit: Graphical Notation

We want to create and implement a software modeling toolkit that supports the proposed notation which allows for decentralized governance design. This can be used a baseline for computational governance, which is our long-term research goal. This work is based on the DECENT meta model, we refer the reader to [3].

Group-Actor Notation.
There is an important difference between an actor and a group. The former models an actor perceived as independent, the latter describes an aggregation of a party. Thus, an actor is not a group, and a group is not an actor. We state that a party is either an actor or a group, hence translating the relation "actors extend parties" and "groups extend parties". There is a semantic difference when an actor, which can independently take a decision, represented as just one actor and a group which takes a decision collectively, represented as multiple actors. We remark that it is possible that a group can consist of groups. A Party, can be a Group or an Actor, uses decision making and voting to modify governance construct according to their role. Group and actor with their associated role [Define, Execute, Monitor] and the decision making that occurs is dynamic. This structure can and will change over time, as governance is not set in stone. The governance construct that a group and actor have to decide over is: goal-objective, Rule Set, Incentive, and Policy-Mechanism. In turn, the governance construct modify group, party, actor, their associated roles and the decision making via a decentralized construction. This is a clear modeling decision that infers decentralization. An important requirement to visualize how an actor and a group reaches a decision via their assigned role and the attribute vote, that affects the governance construct.

Fig. 1.1: Actor Notation

Fig. 1.2: Group Notation

Goal-Objective Notation.
We state that every goal may be associated with numeric parameters via objective. This formalizes the fact that an objective measure and realizes achieving a quantitative stated goal. We remark that it is possible that "a goal consists of multiple goals". For cohesion, we decided that goal and objective can be presented as one icon, represented as two circles. The inner circle represents a goal. The outer circle represents an objective. The circles have the same center however with a different radius compared to the center of the circle as an objective makes the goal measurable and act as refinement of a goal. Concatenation of goal-objective within one notation, reduces complexity and it infers that a goal without an objective, and vice versa cannot be formulated separately.

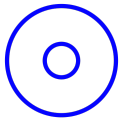


Fig. 1.3: Goal-Objective Notation

Decision Making-Vote Notation.
Decision making is used by a party in a specific role and it refers to a collection of different voting strategies used by a party to take a decision, this occurs via the construction of a vote. Let vote be an attribute of decision making which is represented as a string. Decision making should occur for every governance construct via the decentralized structure of the role that a party plays. For example, to establish a decentralized constellation, role of [Define, Execute, Monitor] and the decision making should be decentralized via several actor/groups, and not concentrated at one party. Decision making is used by a role, which is played by a party, to affect the governance construct. To visualize the decentralized structure decision making should be represented as a rectangle, and with vote upper right within decision making as a diamond shape. The rectangle shape of decision making structures and organizes the governance construct, and implies that everything that occurs within the rectangle, a decision materializes.

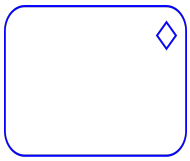


Fig. 1.4: Decision-Vote Notation

Rule Set Notation.
A rule is an elementary concept that cannot be fragmented in smaller rules. Rules are part-of (multiple) rule set(s). Legislation and regulation extend rule sets. Concepts: legislation, regulation, rules form the semantics of the Rule Set. We formalize that a legislation and regulation are two different concepts. Regulation such be formulated as a result of legislation. Legislation and regulation extend rule sets, and we formalize that rule set consists of rules. This structure can be represented into one icon as a rectangle boundary with upper right the scale of justice to achieve equitable governance. This rectangle allows to represent the rules, legislation and regulation in one icon and reduces complexity and couples the rule set in one icon. Legislation, regulation and rules are represented as a string within the rectangle boundary.

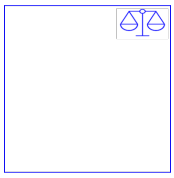


Fig. 1.5: Rule Set Notation

Incentive Notation.
We decided to design Incentive as one icon, as this ensures that consistency is formulated, and balance is achieved. Penalty and reward are represented as a graphical segmentation of a circle acting as two opposites, which form together the semantic of incentive. An incentive is the generalization of penalty or reward. Incentive is a stimulation to achieve objectives and adhere to rules. It has an expression stating the reward or penalty. Incentive can contribute to achieving or implementing adherence to a rule operationalized either as penalty or reward. Penalty can be formulated as a sanction if objectives are not met. Reward is a motivation to achieve objectives. Thus, incentive is a result that follows if a rule is adhered to, or not respected.

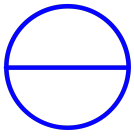


Fig. 1.6: Incentive Notation

Policy-Mechanism Notation.
A policy is a document that is implemented by the mechanism, represented by the icon file explorer. Mechanism is part of policy represented by the icon engine. A policy implements the rule set structure, and incentives extends mechanism. Policy consists of mechanism and is a plan for action. A mechanism implements a rule, is part-of a policy, contributes-to reaching an objective, generalization of incentive, contributes to satisfaction of a goal. It is stated that a mechanism usually is process-oriented and can be represented, for example, by a BPMN model. While many governance mechanisms are indeed process-oriented, there are also those that go beyond processes. A policy is a governance construct that is a clear plan for action and requires implementation.

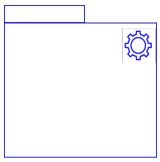


Fig. 1.7: Policy-Mechanism Notation

Relationship Notation The meta model [3] represents eleven relations, to present these all graphically is not in line with our design requirement as it would make it overly complex and difficult to create models. We present three relationships: *role*, *leads to* and *implement*. These relations infer decentralization, and this construction allows to connect several governance constructs to achieve a meta-governance level view, see Table 1.2.

Role Relationship [Define, Execute, Monitor] structure is a decentralized constellation and can prevent centralization. If one specific party uses all roles, it is immediately clear that decentralization is not the main motivation in shaping the digital ecosystem at hand. Role is only visible in the governance construct models, and not at the higher abstract level that represents all governance constructs.

Leads to is a relationship construct that connects the governance constructs: goal-objective, rule set and incentive within a governance model. Ultimately, the governance constructs, are **Implemented** via the governance construct: policy-mechanism.

Table 1.2: DECENT Relation Notation

DECENT Concept	Graphical Notation	Description
Role		The position a party takes related to the governance construct, which can be: Define, Execute or Monitor, represented as a line.
Implements		Governance construct put into effect, represented as a straight line with hallow arrow head.
Leads to		Leads to connects the governance construct, represented as a straight line with a solid arrow.

Role Relationship Notation.
Let [Define, Execute, Monitor] be a set of strings, that are called Roles. A party plays the role assignment structure, by using decision making to affect the governance construct. We remark here, that role is an objectified relationship within the meta model and represented as a relationship with the notation as well. The role relationship structure, uses decision making to affect the governance construct, therefore we have decided to represent the role structure as a relationship noted as a straight black line. We use text here to distinguish the role in detail, which can be: *Define*, *Execute* or *Monitor* when constructing the governance models.

Fig. 1.8: Role Relationship Notation

Leads to Relationship Notation.
We state that goal-objective structures should *lead to* legislation-regulation-rule structure. The *leads to* infers decentralization, as multiple governance constructs should be designed separately and more importantly this relationships links the governance constructs towards implementation. Represented as a straight line with a solid arrow.

Fig. 1.9: Leads to Relationship Notation

Implements Relationship Notation.
Ultimately, all governance constructs should be implemented. This is conceptualized via the governance construct of policy-mechanism. Policy implements, goal-objective, rule set and incentives structures via mechanism. Governance constructs are put into effect, represented as a straight line with hallow arrow head.

Fig. 1.10: Implements Relationship Notation

1.5 Development process in ADOxx

To implement the DECENT graphical notation and the models as a software modeling toolkit, we use the technology of ADOxx®, which is a development and configuration platform for implementing modeling tools[1]. More importantly, ADOxx allows for rapid software prototyping, it supports the implementation of individual modeling languages, modeling processes and corresponding functions such as visualization [10]. The process of creating classes and attributes in ADOxx involves defining the structure of classes (both class and relational) and attributes in the modeling language as well as detailing the scripting language for each class which involves the following steps:

- **Create new classes**: In ADOxx, a class represents a concept or artifact in the modeling language. Classes define the structure and behavior of objects in the model. Create the names of all classes and relational classes based on the DECENT object in the table1.1 1.2.
- **Define attributes:** Attributes define certain characteristics of a class or a relational class. In ADOxx, each attribute contains at least three aspects: name, data type (STRING, INTEGER, DOUBLE...), and value (default or standard value). They provide additional information about the object of the class. A class attribute can receive only one value on a class. Common class attributes used during the development of the DECENT modeling language are names, details, etc.
- **Define GraphRep and AttrRep:** GraphRep is a graphical notation language and AttrRep is a Notebook/Attribute Notation Language, in ADOxx we need to use both development languages for graphical definition of classes and scripting transformations with the built-in interpreter. The class attribute GRAPHREP is of type LONGSTRING, so the attribute value can be considered as a text describing the following types of element information: style, shape, variable

[1] https://www.omilab.org/adoxx/

assignment, contextual elements, and control elements.GraphRep uses coordinate space for precise positioning of various combinations of elements. It consists of the following parts: empty coordinates in the middle, positive values to the right and down, negative values to the left and up. The class property "AttrRep" controls the availability of attributes and designs the structure of ADOxx-Notebook using the characteristics of node objects.

- **Modeling Structure Setting:** For realizing a high-level governance model and four separate governance models to reduce model complexity, we use the "Model pointer" class attribute. The logic is to move the add-on elements of your model to another model type and reference it using an INTERREF attribute on model level.
- **ADL export and import:** After checking the user group assignment and the visualization level of the model, the model language ADL needs to be exported in the ADOxx development toolkit platform and imported into the modeling toolkit platform.

Video Impression DECENT Software Modeling Toolkit in ADOxx.
For an impression how the graphical notation can be used to create DECENT governance models by using the software modeling toolkit, we refer to the following video: https://www.dise-lab.nl/wp-content/uploads/2023/09/DECENT_Modeling-platform_Example.mp4

1.6 Using DECENT to Conceptualize the Digital Euro

We follow the principles of technical action research [11]. The goal of technical action research is the use of an experimental artifact to learn about its effects in practice. The experimental artifact here is the DECENT graphical notation. To learn about the effects of the DECENT governance models, we develop the case of the Digital Euro. This is an important step in order to assess the usability of the DECENT graphical notation and models. The Digital Euro is a digital currency, denominated in the national unit of account, which is a direct liability of a central bank, such as physical cash and central bank settlement accounts. The Digital Euro will allow central banks to regain control of the disparity currently occurring within the financial domain. The development of the Digital Euro is in full swing, and the Digital Euro as proposed by EU is very much ongoing a System under Design (SuDs). In [12] several worldwide initiatives of the Central Bank Digital Currency (CBDC) are analyzed, and concludes that one of the biggest challenges of implementing such a currency, is designing the related governance structures. It is also stated that only a central bank can issue a Digital Euro and is the sole custodian [13]. By introducing the Digital Euro, a central bank can streamline payment transactions to protect privacy of citizens and ensure that citizens and companies have equal access to trustworthy digital payment solutions with no data harvesting occurring. However, how to design and introduce a Digital Euro, since it involves a complex redesign of the financial ecosystem with many participating actors, is identified as a governance design challenge [12].

We visualize the impact of the Digital Euro [14] as represented in Fig 1.11, we observe the impact on the financial balance sheet of the commercial banks with the introduction of the Digital Euro. The lending capacity of the commercial banks is reduced and the reserved of the central bank will increase.

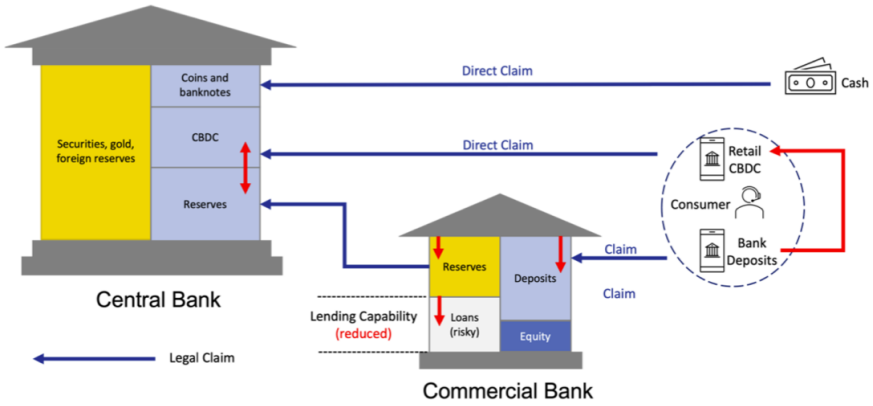


Fig. 1.11: Digital Euro Balance Sheet [14]

1.6.1 Governance Construct Model

In this section we create governance models using the graphical notation for the case of Digital Euro. To give an observation how we created the DECENT governance models, using the DECENT software modeling toolkit, we kindly refer to the following video, which demonstrates how governance models can be created:
https://www.dise-lab.nl/wp-content/uploads/2023/09/DECENT_Modeling-platform_Example.mp4
We now conceptualize and present the Governance Construct: Goal-Objective, Rule-Set, Incentive and Policy-Mechanism as the Governance Construct Digital Euro Model in Fig. 1.12. The model presents a structure that visualizes the most important governance design decisions. Also, the decentralized structure is visible, as each construct *leads to* another construct and visualizes the governance construct should be *implemented* as well. We remark here, that this governance construct model is just a slice of the Digital Euro domain. What follows now is that we explain and present the DECENT governance models per governance construct hereafter in detail.

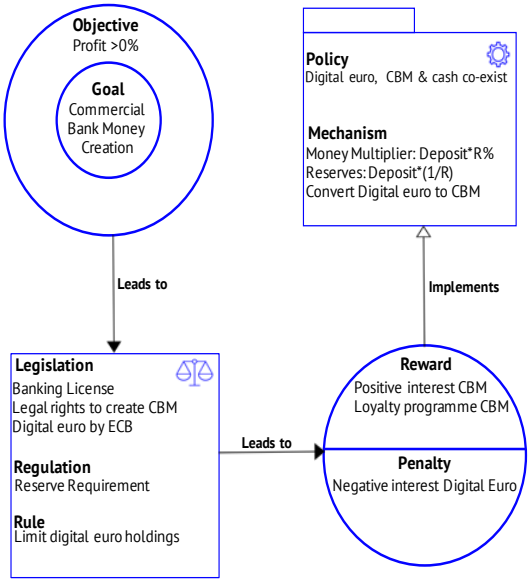


Fig. 1.12: Governance Construct Model: Digital Euro

Digital Euro: Group-Actor Conceptualization.
In order to design the governance models, we first have to understand the structures of the concept *Party*, which is either a group or an actor this is identified as the first design decision. We identified the following *Groups*: European Central Bank, National Central Bank (e.g. De Nederlandse Bank in the Netherlands) and commercial banks. These are groups because all are subjected to comply to the *Legislation* and *Regulation* by European Central Bank and respectively the national central bank in which the latter have an important regulating role. We demarcated customers as an *Actor*. As *Actors*, in principle are solely responsibility for their own economical well-being and actions. An *Actor* will interact both with the Digital Euro, and commercial bank money creation, since the *Group* commercial banks use the assets of a customer to create commercial bank money. It is expected that the commercial banks will have a decreased access and capability to create commercial bank money, as the Digital Euro, will act as a competing currency.

1.6.2 Goal-Objective Model

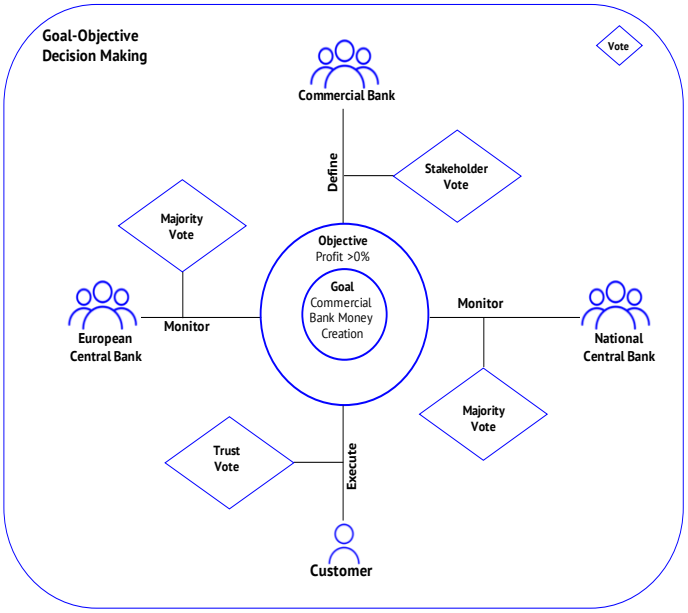


Fig. 1.13: Goal-Objective Model: Digital Euro

What follows now is the conceptualization of the governance construct: Goal-Objective, see Fig. 1.13, it represents the most important constructs and how the Goal-Objective *decision making* is occurring via the voting structure per *Party*. Within the financial domain of Digital Euro, each *Party* has their own (multiple) *Goals*. However, within a decentralized ecosystem a *Goal* and the corresponding *Objective* is not *decided* by just one *Party* as a hierarchical governance structure. Rather, it is decentralized, as the goal-objective model Fig. 1.13 represents. The *Role* and the *Party* structure influences the *Goal-Objective* structures. An important part of the size of an economy is how money is being created and distributed.
The *Group* commercial banks use the money from their customer, which is represented as an *Actor*, to create money via the FRB mechanism. Even within a Digital Euro setting, the *Goal* of the *Group* commercial banks is still to create commercial bank money by using assets from the *Actor* customer. The *Group* commercial bank via *Role* defines the *Goal* of creating commercial bank money, this *Goal* consequently measured by an *objective*. The *Objective* of the *Group* commercial banks is to make profit. Even though the *Group* commercial banks have a defined *Goal-Objective* it is still part of a larger ecosystem, as multiple *Groups* can create commercial bank money. This is subjected to the following governance *Decision making* structures.

1.6.3 Rule-set Model

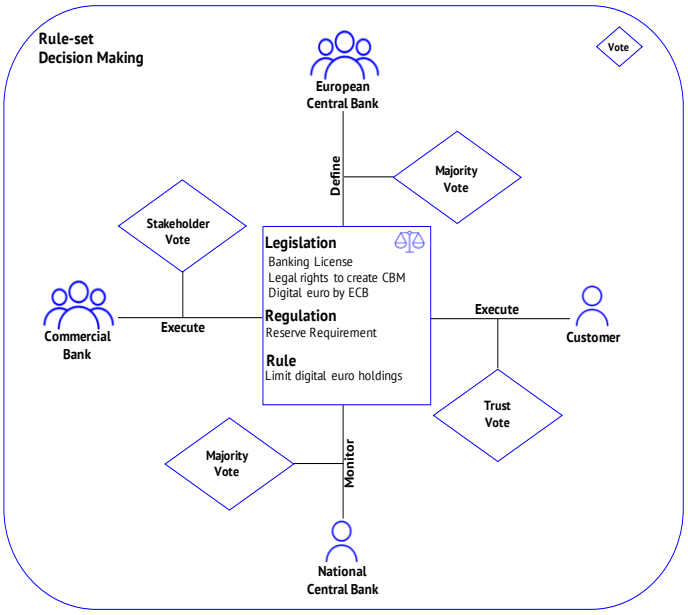


Fig. 1.14: Rule-set Model: Digital Euro

We now conceptualize the Rule-Set Model see Fig. 1.14. The Rule-set follows from design decisions about (1) Party structure and (2) Goal-Objective model as discussed in the previous sections. The *Rule-Set* governance construct consists of: Legislation, Regulation and Rules. These hold a formal and legal grounding in the law, which is solidified by *monitoring* the *rules*. When a commercial bank wants to create commercial bank money as a *Goal*, this is consequently subjected to the *Rule-Set*. First the *Group*, commercial bank needs to obtain a banking license which is *defined* by the *Group*, European Central Bank, and this is defined in *Legislation*. Secondly, the *Group* commercial bank, executes the *legal* right to create commercial bank money, as this is *defined* by the *Group*, European Central Bank. The current payment financial infrastructure of the European Union is heavily dominated by non-European companies. This poses a risk for the stability, as creation and distribution of money within the euro-zone is in hand of non-European companies, that potentially can use their influence to interfere. Therefore, the *Group* European Central Bank *defined* the intention of a *law* to create a Digital Euro, and the distribution shall be *executed* via the *Group* commercial banks. The *Group* national central banks hold an important *regulating* and *monitoring* role. Each national central bank has to *monitor* the amount of money that is created. The Digital Euro will not be a programmable currency as a *Rule*.

1.6.4 Incentive Model

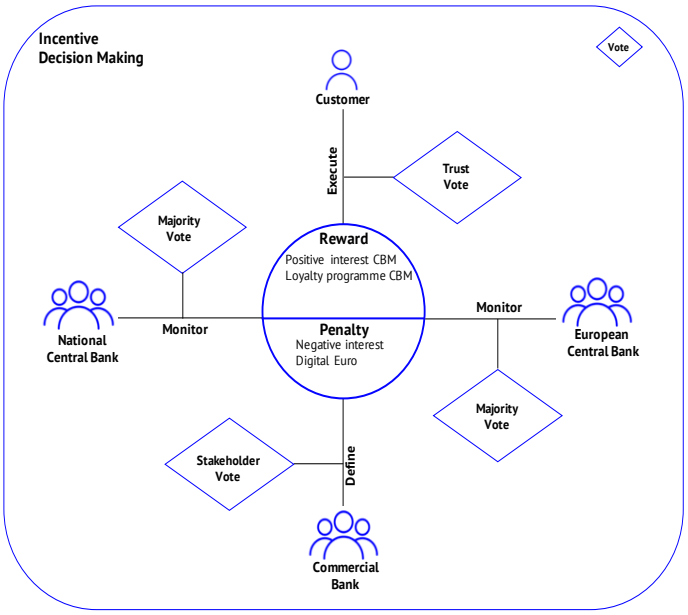


Fig. 1.15: Incentive Model: Digital Euro

We now develop the Incentive Model see Fig. 1.15. We clearly see a realistic clash between the currencies of Digital Euro versus commercial bank money, and how this structure impacts the governance construct *Incentive*. At one hand the Digital Euro will be introduced to unify the European payment infrastructure with as a result decreased dependence on Big Tech companies. However, on the other hand, the Digital Euro is also competing with commercial bank money. To prevent that Digital Euro's would be accumulated as it can be perceived as a stable investment, or even to drive speculation, the *Group* European Central Bank will introduce a *Rule* in place that does not allow an actor to hold more than €500 in their digital wallet per day. This is a structure that is decided by the *monitoring* role of the *Group* European Central Bank. To stimulate the holdings of commercial bank money a positive interest can be accumulated at the digital wallet of *Actor* customers.
The voting structure of the *Actor* customers, which influences trust, is how a customer assets will be stored. Therefore, the *Group* commercial bank introduces a *Reward*, e.g. a loyalty program that will *Reward*, stimulate to convert Digital Euro holdings to commercial bank money. If the *Actor* customers, prefers to hold amounts of Digital Euro, the *Group* commercial bank can *define* a *penalty* of negative interest to discourage large holdings e.g. savings account of the Digital Euro.

1.6.5 Policy-Mechanism Model

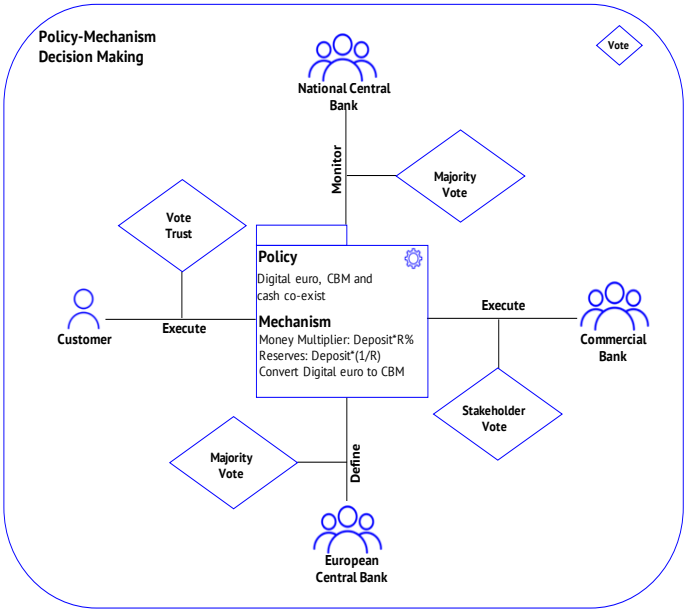


Fig. 1.16: Policy-Mechanism Model: Digital Euro

We now develop the Policy-Mechanism model see Fig. 1.16. A *Policy* is a plan for action, consisting of coherent set of *mechanisms*, to implement a particular *Rule-Set*, *Incentive*, and *Goal-Objective*. The *Policy* that will be *implemented*, are defined in the Rule-Set model see Fig. 1.14. The *Actor* customer has again an influence via *Vote*, even though there are policy and mechanisms in place to create money in the economy, it all ties together via the *vote-trust*. Essentially the *Policy* that will be implemented is that cash (banknotes and coins), Digital Euro and commercial bank money will co-exist. This *Policy* is *defined* by the *Group* European Central Bank, *executed* by the *Group* commercial banks and *monitored* by the national central banks. The *Policy* is implemented by the *Mechanism*. The *Group* commercial banks are not allowed to create commercial bank money infinitely, thus the *mechanism* reserve requirement is implemented, and *monitored* by the *group* National central bank. The *mechanism* money multiplier is *defined* by the *Group* European Central Bank, depending on the state of inflation and price stability, the money multiplier formula is *defined* and is adjusted over time. There is also tension between the Digital Euro that an *Actor* customers can hold versus the commercial bank money.With the introduction of the Digital Euro the *groups* European and national central bank increase their control on the financial domain in how money is created, stored, exchanged and destroyed.

1.7 Conclusion

The governance paradigm has been propelled by a response of society to prevent value extraction by designing digital ecosystems that are decentralized. Emergence of blockchain technology led into experiments in shaping such digital ecosystems. As governance is a topic of design, there is a clear need for software tooling in shaping decentralized ecosystems. A model-based design is an effective approach to manage and design these complex digital ecosystems. To provide scholars and digital ecosystems designers with an intuitive model-based approach of decentralized governance we propose and developed the DECENT software modeling toolkit. This is a model-based design approach, solidified with the meta model, graphical notation and implemented in the software environment of ADOxx. This allows for design, analysis, description and evaluation of DECENT governance models for digital ecosystems. We answer the research question and provide a research outlook for future work.

How can decentralized governance be conceptualized by a graphical notation and supported by software tooling?
We experimented with existing modeling techniques as discussed and we are conclusive that it does not fulfill our design requirements to visualize and design decentralized governance models. Therefore, we developed the DECENT graphical notation, following the conceptualization of decentralized governance design presented as the meta model. The graphical notation is implemented as the DECENT software modeling toolkit. This allows for design, analyze and assessment of decentralized governance models for digital ecosystem design. This work is an important contribution towards operationalizing and implementing governance. The DECENT software modeling toolkit can serve as the starting point to develop computational governance, to facilitate on-chain governance execution, which is our long-term research goal. We developed the DECENT graphical notation for decentralized governance design which allows us to create, assess and analyze governance models. To assess the usability of the graphical notation we applied the DECENT software modeling toolkit to design the governance system of the Digital Euro case. This is about the design and exploration of governance structures of the Digital Euro system.

Future work.
Computational Governance.
Our contribution is a model-based approach to design decentralized governance. A logical next step would be implement and execute the DECENT governance models computationally. Ideally this should be executed via on-chain governance, which may be supported by blockchain technology. Computational governance software should allow for implementing and executing the governance constructs following the design of DECENT governance models.
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