Dynamic Modeling for Optimal Cryptoeconomic Policies

Pitch Proposal 2

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Research Question

How should we design dynamic staking and burning policies?

- Current protocol-coded policies are static even though crypto-economies face dynamic shocks. “Staking” and “burning” rates are the primary coded policy rules in the underlying blockchain system
  - **Staking (increases “token supply”, decreases “tokens in circulation”)**: mint new tokens and give to those who stake their existing tokens as interest. Similar to interest on reserves.
  - **Burning (decreases “token supply”)**: burn (remove from circulation) a portion of the transaction fee paid by users during blockchain transactions
- Policy goal: maximize welfare for good actors: users (increase in token price) and validators (transaction fees)

Literature Review

- Micro foundations:
  Biais et al. (2019), Budish (2018), Gans and Gandal (2019), Gans and Holden (2022), Huberman et al. (2021), and Nisan et al. (2007), etc.
  → **Block reward and transaction fee as incentive mechanisms**
- Pricing models of cryptocurrencies:
  Bitcoin: *Athey et al. (2016), Biais et al. (2020), Bolt and Van Oordt (2020), Catalini and Gans (2020), Chiu and Koeppl (2017), Garratt and Wallace (2018), Hinzen et al. (2022), and Schilling and Uhlig (2019a, 2019b), etc.*
  Proof-of-stake: *Catalini et al. (2020) and Saleh (2019, 2021)*
  → **Static token supply means all shocks are absorbed by price**
- Monetary policies for stablecoins, platform tokens, and CBDCs:
  Cong et al. (2021, 2022), d'Avernas et al. (2022), Fernández-Villaverde et al. (2021), Sockin and Xiong (2023a, 2023b), and Zhu and Hendry (2019), etc.
  → **Optimizing policy for defending peg and/or making profit**

Contribution to the Literature

- Practical: Most cryptoeconomic systems feature fixed-schedule token supply
  - deterministic token supply (Bitcoin), [1] fixed burn rate (Ethereum) [2], naive dynamic burning (Binance Coin)
- No published literature has been established on optimal staking and burning policies for proof-of-stake cryptocurrencies.

Novelty of this research:

- Applies dynamic general equilibrium methods to model and optimize crypto policies for staking and burning
- Traditional models for optimal fiscal policy (e.g. Ramsey) and monetary policy (e.g. NK) are not directly transferrable to cryptoeconomies due to transaction fee role in the cryptoeconomy

[1] Satoshi Nakamoto (2008). Bitcoin: A peer-to-peer electronic cash system

[2] Ethereum Documentation. “Gas and Fees - Base fees”

The baseline model (Biais et al. 2020, Journal of Finance)

Idea: The fundamental value of crypto comes from the stream of future transactional benefits (Tirole, 1985)

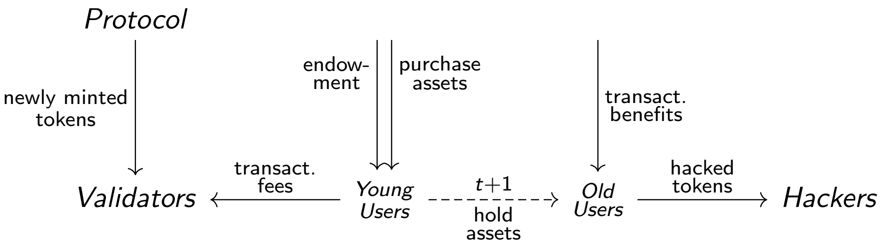
- e.g. access to unique goods, not expropriated/taxed/constrained by government, direct internet access

Setup: Two-period model with overlapping generations

- Three actors: users, validators (miners), hackers
- Three financial assets: a risk-free asset, a standard currency (dollar), a cryptocurrency (Bitcoin)
- Sources of shocks: endowment, transactional benefit, fees

Result: Bitcoin price changes partly due to changes in net transactional benefits, but mostly extrinsic volatility

The baseline model (Biais et al. 2020, Journal of Finance)



In each period:

- **Young users** receive endowment, spend on consumption goods & financial assets. Pay fees on crypto purchased
- **Old users** consume savings (some crypto savings get hacked), and receive transactional benefits
- **Validators** receive newly minted tokens as block rewards
- **Hackers** hack a portion of users' crypto

The baseline model: Users

$$\text{Young users: } c_t^y = e_t - s_t - (1+\varphi_t)q_t p_t - \hat{q}_t \hat{p}_t$$

$$\begin{aligned}\text{Old users: } c_{t+1}^o &= s_t(1+r_t) + (1-h_{t+1})q_t p_{t+1} + \hat{q}_t \hat{p}_{t+1} \\ &+ \theta_{t+1}(1-h_{t+1})q_t p_{t+1}\end{aligned}$$

e_t: endowment
s_t: quantity of risk-free assets held
$q_t, \hat{q}_t$: quantities of crypto and dollars held
$p_t, \hat{p}_t$: prices (in units of consumption goods) of crypto and dollars
h_{t+1}: portion of crypto hacked by hackers
φ_t: transaction fees involved in using crypto (exog.)
θ_{t+1}: transactional benefits from using crypto (exog.) (assume $\theta_{t+1} \geq -1$)

The baseline model: Validators and hackers

$$\text{Validators: } c^v_{t+1} = (X_{t+1} - X_t)p_{t+1} + \varphi_{t+1} q_{t+1} p_{t+1}$$
$$\text{Hackers: } c^h_{t+1} = h_{t+1} q_t p_{t+1}$$

X_t: stock token supply
$X_{t+1} - X_t$: increase in token supply (newly minted tokens)

The baseline model: Market clearing

Markets for financial assets:

$$\begin{aligned} \text{crypto: } & q_t = X_t \\ \text{dollars: } & \hat{q}_t = m \\ \text{risk-free assets: } & s_t = 0 \end{aligned}$$

Market for consumption goods (by Walras's Law):

$$c_t^y + c_t^o + c_t^v + c_t^h = e_t$$

The baseline model: Solution

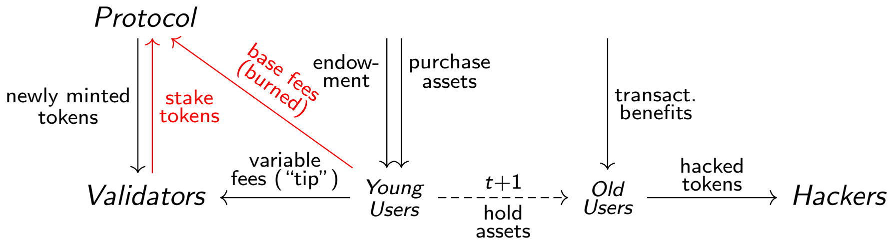
A young user in period t solves:

$$\max_{s_t, q_t, \hat{q}_t} u(c_t^y) + \beta \mathbb{E}_t u(c_{t+1}^o)$$
$$\text{s.t. } c_t^y \geq 0$$

* Information set at period t includes $\{\theta_t, \varphi_t, \pi_t\}$
From FOCs obtain the equilibrium pricing equation:

$$p_t = \underbrace{\frac{1}{1+r_t}}_{\text{discount}} \mathbb{E}_t \Bigg[\underbrace{\frac{u'(c_{t+1}^o)}{\mathbb{E}_t[u'(c_{t+1}^o)]}}_{\text{risk-neutral prob}} \underbrace{(1 - h_{t+1})}_{\text{hack risk}} \underbrace{\frac{1+\theta_{t+1}}{1+\varphi_t}}_{\substack{\text{net transact.} \\ \text{benefits}}} p_{t+1} \Bigg] \tag{1}$$

Extension 1: Endogenous token supply



I introduce:

- Two-part transaction fee with burning
- Interest-bearing staking
- The protocol controls the staking yield (“interest rate”) and the base transaction fee rate (burn rate)

Introducing staking and burning

Staking: L_t: amount of staked tokens, δ_t: staking yield (set by protocol)
Burning: φ_t^b: base fee (set by protocol); φ_t^v: variable fee (competitively determined by validators and users)

New budget constraints:

$$
\begin{aligned}
\text{Young users: } c_t^{u,y} &= e_t^u - s_t - (1 + \varphi_t^b + \varphi_t^v) q_t p_t - \hat{q}_t \hat{p}_t \\
\text{Old users: } c_{t+1}^{u,o} &= s_t(1 + r_t) + (1 - h_{t+1}) q_t p_{t+1} + \hat{q}_t \hat{p}_{t+1} \\
&\quad + \theta_{t+1}(1 - h_{t+1}) q_t p_{t+1} \\
\text{Young validators: } c_t^{v,y} &= e_t^v - L_t p_t \\
\text{Old validators: } c_{t+1}^{v,o} &= \delta_t L_t p_{t+1} + \varphi_{t+1}^v q_{t+1} p_{t+1} \\
\text{Hackers: } c_{t+1}^h &= h_{t+1} q_t p_{t+1}
\end{aligned}
$$

Token supply with staking and burning

$$
\begin{aligned}
M_{t+1} &= (M_t - L_t) + L_t(1+\delta_t) - \varphi_t^b X_t \\
&= M_t + \delta_t L_t - \varphi_t^b X_t
\end{aligned}
$$

M_t: total token supply
$X_t \equiv M_t - L_t$: circulating supply
$\Rightarrow$ Now market clearing condition is $X_t = q_t$

* In reality the total reward is $\delta_t L_t^{\alpha}$, with pre-set $\alpha \in [0,1]$[3]. Here I set $\alpha = 1$ WLOG since δ_t is dynamic.

[3] Ethereum Documentation. "Proof-of-Stake Rewards and Penalties"

Validator's problem

$$\max_{L_t} u(e_t^v - L_t p_t) + \beta \mathbb{E}_t u(\delta_t L_t p_{t+1} + \varphi_{t+1}^v q_{t+1} p_{t+1})$$
$$\text{s.t. } q_{t+1} \leq M_{t+1} - L_{t+1}$$

Trade-off:

$$\text{more staking at } t \Rightarrow \begin{cases} \text{more staking yield at } t+1 \\ \text{less circulating supply} \Rightarrow \text{less transact. fees at } t \end{cases}$$

Apply Karush-Kuhn-Tucker to solve the optimization problem

Next Steps

- **The model:** Finish extended model with staking and burning, obtain analytical solution for equilibrium pricing, run simulations using dynare / Python
- **Replicate calibration:** Replicate calibration for baseline model (authors provided full replication code in Python)
- **Get data on Ethereum:**
  - ETH price data: Messari API[4] (REST) and Dune Analytics[5] (SQL database with execution API in Python)
  - ETH staking and burning data: Beacon Chain[6] (REST)
- **Calibrate my model**: get ideas after replicating calibration

[4] https://messari.io/api
[5] https://dune.com/docs/api
[6] https://ethereum.github.io/beacon-APIs

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