Dynamic Modeling for Optimal Cryptoeconomic Policies

Pitch Proposal

Mingxuan He

M.A. in Computational Social Science – Economics
Department of Economics, University of Chicago
mingxuanh@uchicago.edu

April 25, 2023

Table of Contents

Research Question

How should we design cryptoeconomic policies (staking and burning) that respond dynamically to endogenous and exogenous shocks?

- Most crypto monetary policies today are static:
  - deterministic token supply (Bitcoin), fixed burn rate (Ethereum), naive dynamic burning (Binance Coin)
- Problems occur in the long term due to the abundance of shocks & lack of response mechanisms
- This can be addressed by implementing dynamic policies:
  - **Staking (increases money supply)**: mint new tokens and give to those who stake their existing tokens as interest yield
  - **Burning (decreases money supply)**: burn (remove from circulation) a portion of the transaction fee paid by users during blockchain transactions
- Policy goal: maximize welfare for good actors (i.e. users and validators) in the economy

Contributions to the Literature

Gaps in the literature:

- Most cryptoeconomic models feature fixed-schedule money supply
- Traditional models for optimal fiscal policy (e.g. Ramsey) and monetary policy (e.g. NK) are not directly transferrable to cryptoeconomies due to extra frictions in the cryptoeconomy
- No literature has been established on optimal economic policies for proof-of-stake cryptocurrencies in general (some on CBDC and stablecoins)

Novelty of this research:

- Applies dynamic general equilibrium methods to model and optimize crypto policies for staking and burning

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)*
  → **Exogenous money 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), and Zhu and Hendry (2019), etc.
  → **Central planner approach to supply of tokens**

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

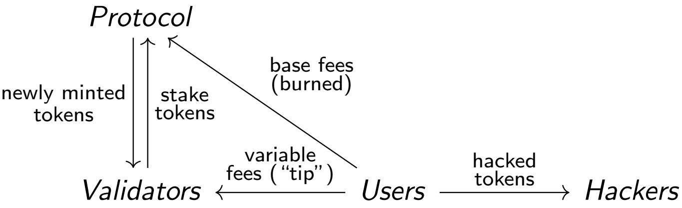
The baseline model (Biais et al. 2020, Journal of Finance)

$$
\begin{tikzcd}
\textit{Protocol} \arrow[d, "\text{Newly minted tokens}"'] & & \\
\textit{Validators} & \textit{Users} \arrow[l, "\text{transact. fees}"'] \arrow[r, "\text{hacked tokens}"] & \textit{Hackers}
\end{tikzcd}
$$

In each period:

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

Extensions to the baseline model: endogenous money supply



We introduce:

- Two-part transaction fee with burning
- Interest-bearing staking
- The protocol controls the staking rate ("interest rate") and the base transaction fee rate (i.e. burn rate)

More extensions to model & estimation

1. Modify validators' budget constraint: incorporates costs of validation under PoS and PoW (Biais et al., 2019; Saleh, 2019, 2021)
2. Use vector autoregression models for exogenous process in variable transaction fees and transaction benefit (e.g. sign restrictions)
3. Improvement in model calibration
   - novel time series data on Ethereum price and transaction fees
   - estimate transactional benefits using the NVT (network value to transaction ratio) or RVT (realized value to transaction ratio) metric

Proposed Project Timeline

- Spring '23: As final project for ECMA33603 (Macro & Financial Frictions), replicate the baseline model and implement extensions part 1 (endogenous money supply)
- Summer '23: More model modifications and seek analytical solutions; gather ideas from industry internship in Ethereum research & dev
- Fall '23 - Winter '24: Data collection, model calibration (likely using Ethereum data)
- Spring '24: Finish paper

References

Athey, S., Parashkevov, I., Sarukkai, V., & Xia, J. (2016). *Bitcoin pricing, adoption, and usage: Theory and evidence* (tech. rep.). Stanford University Graduate School of Business Research Paper.

Biais, B., Bisiere, C., Bouvard, M., & Casamatta, C. (2019). The blockchain folk theorem. *The Review of Financial Studies*, *32*(5), 1662–1715.

Biais, B., Bisiere, C., Bouvard, M., Casamatta, C., & Menkveld, A. J. (2020). Equilibrium bitcoin pricing. *The Journal of Finance*.

Bolt, W., & Van Oordt, M. R. (2020). On the value of virtual currencies. *Journal of Money, Credit and Banking*, *52*(4), 835–862.

Budish, E. (2018). *The economic limits of bitcoin and the blockchain* (tech. rep.). National Bureau of Economic Research.

Catalini, C., & Gans, J. S. (2020). Some simple economics of the blockchain. *Communications of the ACM*, *63*(7), 80–90.

References

Catalini, C., Jagadeesan, R., & Kominers, S. D. (2020). Markets for crypto tokens, and security under proof of stake. *Available at SSRN 3740654*.

Chiu, J., & Koeppl, T. V. (2017). The economics of cryptocurrencies–bitcoin and beyond. *Available at SSRN 3048124*.

Cong, L. W., Li, Y., & Wang, N. (2021). Tokenomics: Dynamic adoption and valuation. *The Review of Financial Studies*, *34*(3), 1105–1155.

Cong, L. W., Li, Y., & Wang, N. (2022). Token-based platform finance. *Journal of Financial Economics*, *144*(3), 972–991.

d'Avernas, A., Maurin, V., & Vandeweyer, Q. (2022). Can stablecoins be stable? *University of Chicago, Becker Friedman Institute for Economics Working Paper*, (2022-131).

References

Fernández-Villaverde, J., Sanches, D., Schilling, L., & Uhlig, H. (2021). Central bank digital currency: Central banking for all? *Review of Economic Dynamics*, *41*, 225–242.

Gans, J. S., & Gandal, N. (2019). *More (or less) economic limits of the blockchain* (tech. rep.). National Bureau of Economic Research.

Gans, J. S., & Holden, R. T. (2022). *Mechanism design approaches to blockchain consensus* (tech. rep.). National Bureau of Economic Research.

Garratt, R., & Wallace, N. (2018). Bitcoin 1, bitcoin 2,....: An experiment in privately issued outside monies. *Economic Inquiry*, *56*(3), 1887–1897.

Hinzen, F. J., John, K., & Saleh, F. (2022). Bitcoin's limited adoption problem. *Journal of Financial Economics*, *144*(2), 347–369.

References

Huberman, G., Leshno, J. D., & Moallemi, C. (2021). Monopoly without a monopolist: An economic analysis of the bitcoin payment system. *The Review of Economic Studies*, *88*(6), 3011–3040.

Hurwicz, L., & Reiter, S. (2006). *Designing economic mechanisms*. Cambridge University Press.

Nisan, N., Roughgarden, T., Tardos, E., & Vazirani, V. V. (2007). *Algorithmic game theory*. Cambridge university press.

Saleh, F. (2019). *Volatility and welfare in a crypto economy* (Vol. 3235467). SSRN.

Saleh, F. (2021). Blockchain without waste: Proof-of-stake. *The Review of financial studies*, *34*(3), 1156–1190.

Schilling, L., & Uhlig, H. (2019a). Currency substitution under transaction costs. *AEA Papers and Proceedings*, *109*, 83–87.

References

Schilling, L., & Uhlig, H. (2019b). Some simple bitcoin economics. *Journal of Monetary Economics*, *106*, 16–26.

Tirole, J. (1985). Asset bubbles and overlapping generations. *Econometrica: Journal of the Econometric Society*, 1499–1528.

Voshmgir, S., Zargham, M., et al. (2019). Foundations of cryptoeconomic systems. *Research Institute for Cryptoeconomics, Vienna, Working Paper Series/Institute for Cryptoeconomics/Interdisciplinary Research*, *1*.

Yermack, D. (2015). Is bitcoin a real currency? an economic appraisal. In *Handbook of digital currency* (pp. 31–43). Elsevier.

Zhang, Z., Zargham, M., & Preciado, V. M. (2020). On modeling blockchain-enabled economic networks as stochastic dynamical systems. *Applied Network Science*, *5*(1), 1–24.

References

Zhu, Y., & Hendry, S. (2019). *A framework for analyzing monetary policy in an economy with e-money* (tech. rep.). Bank of Canada Staff Working Paper.

The baseline model: Users

$$\text{Young users: } c_t^y = e_t - s_t - (1+\varphi_t)q_t p_t - \hat{q}_t \hat{p}_t$$
$$\text{Old users: } c_{t+1}^o = s_t(1+r_t) + (1-h_{t+1})q_t p_{t+1} + \hat{q}_t \hat{p}_{t+1} + \theta_{t+1} q_t p_{t+1}$$

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:

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