Product market competition with crypto tokens and smart contracts

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October 2020

Crypto tokens and smart contracts: Overview

What is a crypto token?

- A **crypto token** gives its owner a cryptographically secured right to:
    - Redeem the token for the right to use software/network/platform/product (**"utility tokens"**)
        - A venture issuing tokens **commits to accept them as the sole means of payment** for the software/network/platform/product
    - Future share of revenues/earnings (**"security tokens"**)
    - Security tokens may evolve into utility tokens
- The value of a crypto token can be thought of as the value of:
    - An **option on the flow of revenues** (in a dynamic setting)
    - A **share of revenues** (in a static setting)

Issuance of tokens

- Usually tokens are issued in an **Initial Coin Offering (ICO)** or some variant thereof:
  - Security Token Offering (STO)
  - Initial Exchange Offering (IEO)
  - ...
- Over 6,000 ICOs (including IEOs and STOs), mostly since 2017
- Volume of ICOs (and IEOs and STOs):
  - $<$ 100 million in 2016
  - \$4 billion in 2017
  - \$26 billion in 2018
  - \$6 billion in 2019-2020
- 4 times more financing of blockchain startups through ICOs than through VC investments over the last 4 years

Why do ventures issue crypto tokens?

- Easy way to obtain financing
    - Fast (requires writing a few lines of code)
    - Cheap (very low transaction costs)
    - Less regulated than other forms of financing (in some jurisdictions)
    - Global investor outreach (with caveats)
- Retention of control rights
- Ability of combining financing with building a customer base
- Elicitation of demand information
- Diversification of entrepreneurs' cash flow rights
- Potential mitigation of agency problems associated with equity

What is a smart contract?

- A program that specifies **rules that govern transactions of digital assets**
  - Typically written on top of the same blockchain on which a crypto token resides
- Smart contracts are **executed automatically** when relevant conditions are met
  - Immune from ex-post incentive incompatibility
  - Typically preclude renegotiation
  - Credible commitments to future actions

Motivation

Example of a crypto token

- **FIL** – a token issued by Filecoin in one of the largest ICOs in 2017 (raised $257MM)
- Aims to provide a decentralized network for digital storage through which users can rent out their spare capacity in return for FIL tokens
- Expects to **compete with:**
  - Existing decentralized storage platforms (such as Storj and Sia)
  - Large players in the more broadly defined cloud storage market, such as Dropbox (controlling 77% of the market in 2017), Google Drive, OneDrive, and Box

This paper

- Examines **benefits and costs of issuing crypto tokens and using smart contracts** in a setting in which an entrepreneurial venture expects to **compete in an already existing market**
    - A model of **duopolistic competition with switching costs**, in which firms have the **option of using crypto tokens and smart contracts**
    - Shows that in addition to existing benefits of ICOs **at the financing stage**, there are **benefits at the product market competition stage** due to ability of crypto tokens and smart contracts to **commit the venture to certain output market strategies**
        - On the flip side, pricing in crypto tokens and using smart contracts may lead to higher equilibrium product prices, **hurting consumers**

Contributions to the literature

- Benefits and costs of issuing crypto tokens
  - Bakos and Halaburda (2019), Catalini and Gans (2018), Chod and Lyandres (2020), Cong, Li and Wang (2020a,b), Li and Mann (2019), Malinova and Park (2018), Sockin and Xiong (2020)
  - The first model to consider a **multi-firm setting**
  - The first model to examine **non-financing-related benefits** of crypto tokens
- Benefits of blockchain technology and smart contracts
  - Abadi and Brunnermeier (2018), Catalini and Gans (2018), Cao, Cong and Yang (2019), Chiu and Koeppl (2019), Cong and He (2019), Saleh (2019), Yermack (2017)
  - The first model to consider **commitment to future prices**
- Competition with switching costs
  - Beggs and Klemperer (1992), Biglaiser, Kremer and Dobos (2013), Farrell and Shapiro (1988), Farrell and Gallini (1988), Farrell and Klemperer (2007), Klemperer (1987a, 1987b, 1995), Padilla (1992, 1995))
  - The first model to consider **prices quoted in units of crypto tokens and price commitment via smart contracts**

(Benchmark) model setup

Benchmark model setup I

- 2 firms – incumbent (i) and entrant (e), competing a-la Bertrand
    - i operates for 2 periods
    - e enters in period 2, with zero entry cost
- In both periods, fixed and marginal production costs are zero
- i maximizes the sum of its (expected) profits over two periods by setting prices, p_1 and $p_{2,i}$, in the two periods
- e maximizes its 2nd-period (expected) profit by setting price, $p_{2,e}$
- In period 1, the mass of customers is Q_1 and their valuations of i's product are distributed according to $\mathbb{U}(0,1)$
- The first-period demand for i's product is, thus:

$$q_1 = Q_1(1 - p_1)$$

Benchmark model setup II

- In period 2, the mass of consumers is $Q_2 = Q_1(1+g)$, where $g \geq 0$
- Firms set their product prices simultaneously and non-cooperatively and cannot alter them (e.g., due to "menu costs")
- There are two types of consumers in period 2:
  - Mass q_1 of consumers who bought from i in period 1 (**attached customers**)
  - Mass $Q_1(1+g) - q_1$ of **new customers**
  - Both types of customers' valuations are distributed according to $\mathbb{U}(0,1)$
  - Attached customers have large switching costs ⇒ can buy from i only
  - New customers buy from e if $p_{2,e} < p_{2,i}$ and from i otherwise
- The two firms' second-period demand functions are:

$$q_{2,i} = q_1(1-p_{2,i}) + [(Q_1(1+g) - q_1)(1-p_{2,i})\mathbb{I}_{p_{2,i} \leq p_{2,e}}]$$

$$q_{2,e} = (Q_1(1+g) - q_1)(1-p_{2,e})\mathbb{I}_{p_{2,e} < p_{2,i}}$$

Benchmark model – 2nd-period solution II

Lemma

There exist no pure-strategy Nash equilibria in $p_{2,i}$ and $p_{2,e}$.

- **Intuition:**
  - For any $p_{2,i}$, e's optimal response is to charge $p_{2,e} \nearrow p_{2,i}$
  - The incumbent has the following choice:
    - Charge $p_{2,i} = \frac{1}{2}$ to capture monopoly rent from attached customers
    - Charge $p_{2,i} \nearrow p_{2,e}$ to capture the entire market
    - i prefers to charge $p_{2,i} = \frac{1}{2}$ if $p_{2,e} \leq \underline{p}$

Benchmark model – 2nd-period solution II

Lemma

There exists a unique mixed strategy Nash equilibrium, in which the c.d.f.'s of $p_{2,i}$ and $p_{2,e}$ are between $\underline{p} < \frac{1}{2}$ and $\frac{1}{2}$.

- **Intuition:**
  - It is never optimal for i to charge $p_{2,i} > \frac{1}{2}$ or $p_{2,i} < \underline{p}$
  - In the range $\underline{p} \leq p_{2,i} < \frac{1}{2}$, $\mathbb{E}(\Pi_e)$ is the same for all $p_{2,i} \Rightarrow$ there are no point masses on $\underline{p} \leq p_{2,i} < \frac{1}{2}$
  - Since $\mathbb{E}(\Pi_e) > 0$ for $p_{2,i} = \frac{1}{2}$, there has to be a point mass on $p_{2,i} = \frac{1}{2}$
  - It is never optimal for e to charge $p_{2,e} \geq \frac{1}{2}$ or $p_{2,i} < \underline{p} - \epsilon$
  - In the range $\underline{p} - \epsilon \leq p_{2,e} < \frac{1}{2}$, $\mathbb{E}(\Pi_i)$ is the same for all $p_{2,e} \Rightarrow$ there are no point masses on $\underline{p} - \epsilon \leq p_{2,e} < \frac{1}{2}$

Benchmark model – 1st-period solution I

- i's first-period problem:

$$\max_{p_1} \mathbb{E}(\Pi_i) = \max_{p_1} [\Pi_{1,i} + \mathbb{E}(\Pi_{2,i}(q_1))]$$

where

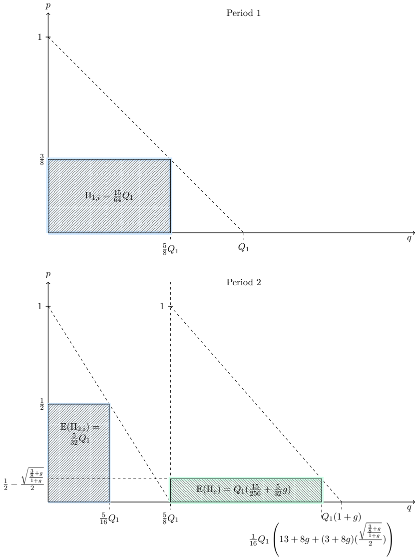
$$\Pi_{1,i} = Q_1(1 - p_1)p_1$$

$$\mathbb{E}(\Pi_{2,i}(q_1)) = \frac{1}{4} q_1 = \frac{1}{4} Q_1(1 - p_1)$$

- Thus, i's problem reduces to:

$$\max_{p_1} \mathbb{E}(\Pi_i) = \max_{p_1} [Q_1(1 - p_1)p_1 + \frac{1}{4} Q_1(1 - p_1)]$$

Benchmark model – equilibrium (*Lemma 2*)



Entrant issues crypto tokens

Model with crypto tokens I

- Prior to product market competition, e issues Θ_e crypto tokens
  - Commits to accept them as the sole means of payment for its product
  - Quotes the price for its product in units of tokens, $\theta_{2,e}$
  - Sells the tokens to interested consumers for a price determined in equilibrium
- In equilibrium, the price of a token (i.e. the exchange rate, $\rho_{2,e}$) adjusts to:

$$\rho_{2,e} \nearrow \frac{p_{2,i}}{\theta_{2,e}}$$

  - There are no customers that would be willing to pay more than $\frac{p_{2,i}}{\theta_{2,e}}$ for e's tokens
  - New customers would be willing to pay up to $\frac{p_{2,i}}{\theta_{2,e}}$
- Implicit assumptions:
  - The price is quoted in e's proprietary token
  - There is liquid market for e's token
  - There are no speculators biasing the token's price

Model with crypto tokens II

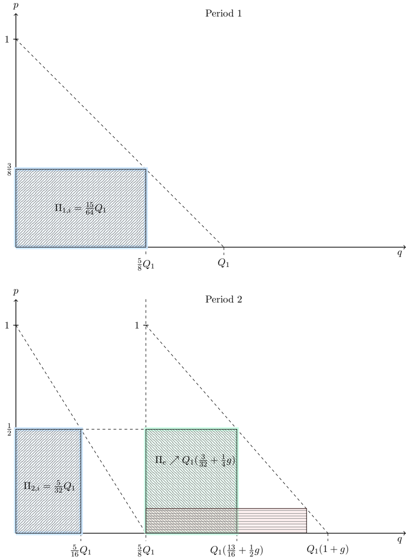
- e's and i's second-period quantities are:

$$q_{2,e} = \min\left[(Q_1(1+g) - q_1)(1 - \rho_{2,e}\theta_{2,e}), \frac{\Theta_e}{\theta_{2,e}}\right]$$

$$q_{2,i} = \left(q_1(1 - p_{2,i}) + \max\left[0, (Q_1(1+g) - q_1)(1 - p_{2,i}) - \frac{\Theta_e}{\theta_{2,e}}\right]\right)$$

- In equilibrium, e chooses $\theta_{2,e} \leq \frac{\Theta_e}{Q_1(1+g)}$
  - i is excluded from selling to new customers in equilibrium ⇒ extracts monopoly rent from attached customers
  - e's equilibrium fiat-currency-equivalent price, $\rho_{2,e}\theta_{2,e}$, approaches monopolistic price

Model with crypto tokens – equilibrium (*Lemma 3*)



Comparison between pricing in tokens and pricing in fiat currency

Proposition

Entrant's equilibrium profit is higher if it prices its output in units of crypto tokens than if it prices its output in units of fiat currency.

- **Intuition:**
  - In equilibrium with fiat currency pricing, $\mathbb{E}(\Pi_e)$ is equivalent to e's profit from serving new customers and charging them $p_{2,e} = \underline{p}$
  - In equilibrium with pricing with tokens, e captures monopolistic rent from new customers

Pricing in units of crypto token – real-world examples

- Filecoin – decentralized data storage
- iExec – decentralized marketplace for performing computations
- Golem – decentralized marketplace for computing power
- Brave – internet browser

Entrant commits to future product price using smart contract

Price commitment with fiat currency

- Price commitment in units of fiat currency is typically **not credible and time inconsistent**
  - Farrell and Gallini (1988), Nocke and Peitz (2007), Su and Zhang (2008), Holden and Malani (2019)
- It also turns out that price commitment in fiat currency would be **detrimental to e's profit**
  - $\underline{p'}$ is such that even if i decides to extract monopolistic rent in the 1st period (resulting in lower mass of attached customers), i would not want to undercut e by charging $p_{2,i} < \underline{p'}$
  - $\underline{p'} < \underline{p} \Rightarrow e$'s profit is lower with price commitment in fiat currency than without price commitment

Price commitment using a smart contract

- Assume that in addition to issuing crypto tokens, e can **commit to future price (in units of tokens)** of its product
  - Commitment to high enough output price, $\theta_{2,e}$, is a de-facto **quantity constraint** on the entrant, as $q_{2,e}$ is bounded by $\frac{\Theta_e}{\theta_{2,e}}$
  - **Potential benefit** of self-imposed quantity constraint:
    - i has a "guaranteed" customer base in period 2
    - this mitigates i's incentives to increase the mass of attached customers
    - and increases i's 1st-period profit
    - As a result, e may capture a larger share of 2nd-period market
- Price commitment using a smart contract can be:
  - **Unconditional**
  - **Conditional** on i's product price
    - Akin to a derivative, which is the type of smart contracts that is very common and easy to implement in code (e.g., Buterin (2014))

Smart contract with unconditional price commitment I

- Facing e's constraint, $\widehat{q_{2,e}} = \frac{\Theta_e}{\theta_{2,e}}$, i can adopt one of the following strategies:
  - Focus on obtaining monopolistic rent in the 2nd period from attached customers and building their mass in the 1st period $\Rightarrow \Pi_i$ is the same as without e's price commitment
  - Obtain monopolistic rent in the 1st period and rely on profit from both (a lower mass of) attached and some new customers in the 2nd period
    - This strategy is more attractive the more binding e's constraint
    - There is a threshold $\overline{q_{2,e}}$, below which (i.e. $\overline{\theta_{2,e}}$, above which) i chooses the second strategy (*Lemma 4*)

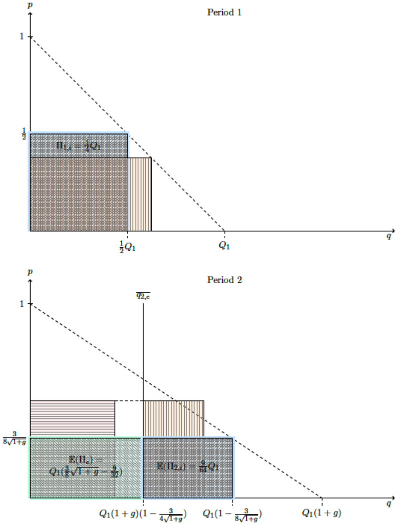
Smart contract with unconditional price commitment II

- If e chooses $\widehat{q_{2,e}} = \frac{\Theta_e}{\theta_{2,e}} > \overline{q_{2,e}}$, equilibrium Π_e is the same as without price commitment
- Here we examine the case in which e chooses $\widehat{q_{2,e}} = \frac{\Theta_e}{\theta_{2,e}} \leq \overline{q_{2,e}}$
    - In the 2nd period, i maximizes $(Q_1(1+g)(1-p_{2,i}) - q^*_{2,e})p_{2,i}$
    - Equilibrium $p_{2,i} = \frac{Q_1(1+g)-q^*_{2,e}}{2Q_1(1+g)}$
- e chooses $q^*_{2,e} = \frac{1}{2}Q_1(1+g)$ (unconstrained optimal $q_{2,e}$ given i's anticipated response) or $\widehat{q_{2,e}}$, whichever is lower
    - Equilibrium Π_e is given by:

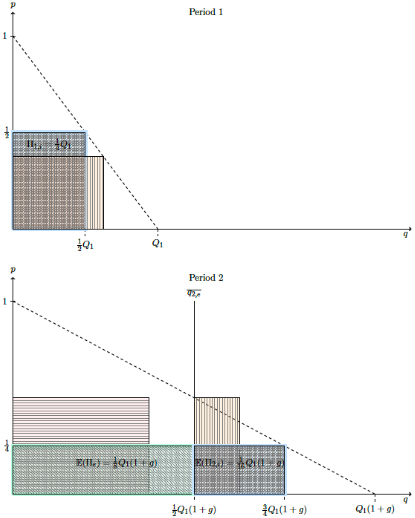
$$\Pi_e = \min\left(\frac{1}{2}Q_1(1+g), \widehat{q_{2,e}}\right) \frac{Q_1(1+g) - \inf\left(\frac{1}{2}Q_1(1+g), \widehat{q_{2,e}}\right)}{2Q_1(1+g)}$$

- As a result, if $g > \overline{g}$, e chooses $q^*_{2,e} = \frac{1}{2}Q_1(1+g)$, and if $g \leq \overline{g}$, e chooses $q^*_{2_e} = \overline{q_{2,e}}$ (*Lemma 5*)

Smart contract with unconditional price commitment – equilibrium (low growth) (*Lemma 5*)



Smart contract with unconditional price commitment – equilibrium (high growth) (*Lemma 5*)



Comparison between pricing with tokens with and without unconditional price commitment

Proposition

Entrant's equilibrium profit is smaller if it commits to second-period output price in tokens than if it does not.

- **Intuition:**
  - There are **two effects of commitment to future prices in tokens** on e's profit:
    - $+$: i's incentive to invest in market share in the 1st period ↓, its 1st period profit ↑, and it is willing to give up market share in the 2nd period
    - –: Since i is the "residual claimant" on 2nd-period new customers' demand, it reduces $p_{2,i}$ below monopolistic level to capture more of the residual demand
  - For both high-growth and low-growth scenarios, the **negative effect on Π_e dominates**

Smart contract with conditional price commitment I

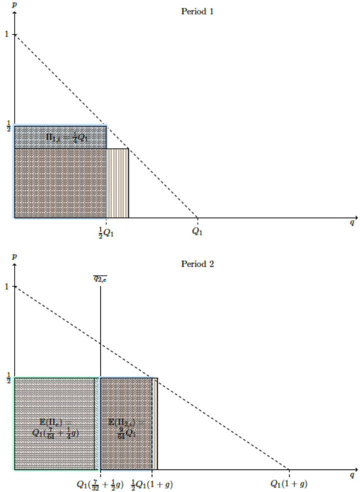
- The **problem with unconditional commitment** is that *i* charges a low price to capture larger market share

- Assume that *e*'s smart contract takes the following form:

  Conditional commitment:
  If i sets its second-period output price at $p_{2,i} = p_2^*$ *then e's output price in crypto tokens would be* $\theta_{2,e}^*$.
  If i sets its second period price at any $p'_{i,2} < p_2^*$ *then e's output price would be* $\theta'_{2,e} < \theta_{2,e}^*$.

  - Thus, the optimal conditional smart contract takes the following form (*Lemma 6*)
    - **Equilibrium strategy:** θ_{2_e} is such that if $p_{2,i} = \frac{1}{2}$ then *i*'s profit is infinitesimally larger than in case of no price commitment
    - **Off-equilibrium (punishment) strategy:** $\theta_{2,e} \rightarrow 0$ if $p_{2,i} < \frac{1}{2}$

Smart contract with conditional price commitment – equilibrium (*Lemma 6*)



Comparison between pricing with tokens with and without conditional price commitment

Proposition

Entrant's equilibrium profit is larger if it uses a properly structured conditional second-period output price commitment than if it uses no output price commitment.

- **Intuition:**
  - i extracts monopolistic rent from 1st-period consumers
  - i is forced to charge monopolistic price in the 2nd period, and is willing to obtain smaller overall sales in the 2nd period (from a lower mass of attached customers and some mass of new customers)
  - e captures a larger share of a larger mass of unattached customers, while charging them monopolistic price

Incumbent issues crypto tokens

Incumbent issues crypto tokens I

- So far, the assumption was that only e could issue crypto tokens
- Now, i is allowed to also issue tokens and price its output in tokens in the 2nd period
- In all scenarios considered so far, Π_i is independent of demand growth, g
  - Equilibrium Π_i is equivalent to the profit from the strategy of building a large base of attached customers in the 1st period and extracting monopolistic rent in the 2nd period
- i may consider pricing its product in tokens if it wants to tap into the demand of new (unattached) customers in the 2nd period

Incumbent issues crypto tokens II

- *i* and *e* are **both allowed to issue crypto tokens** and price their products in units of tokens
- However, **unconditional and conditional smart contracts are not allowed**
- **Reason:** A setting with simultaneous choices by *i* and *e* is not ideal for studying competition in price commitment using smart contracts
  - Price commitment in tokens leads to capacity-price competition, which, under mild assumptions, is equivalent to Cournot competition (Scheinkman and Kreps (1983) and Osborne and Pitchik (1986))
  - The usual tâtonnement argument of adjustment to a Cournot-Nash equilibrium cannot be applied to competition in smart contracts
  - An order in which firms introduce smart contracts is of extreme importance

Incumbent issues crypto tokens – equilibrium

- If i does not issue tokens, e **prefers to issue tokens** (*Proposition 1*)
- If i issues tokens, e **prefers to issue tokens as well**, as otherwise its profit is zero
- If both i and e issue tokens, then for large enough g, there is capacity-price competition in the 2nd period, and the mass of i's attached customers is irrelevant (*Lemma 7*)

Proposition

1. If $g > \overline{\overline{g}}$, i prices its second-period output in crypto tokens.
2. If $g \leq \overline{\overline{g}}$, i prices its output in fiat currency.

- **Intuition**: The only way for i to tap into new customers' demand is to price its product in tokens, as otherwise $p_{2,i}$ is always marginally higher than fiat-currency-equivalent $p_{2,e} = \rho_{2,e}\theta_{2,e}$

Conclusions

Conclusions

- The first paper to examine effects of issuing crypto tokens **in a competitive setting**
  - Pricing output in tokens has **two advantages for the entrant** over pricing in fiat currency
    - Entrant's product price is marginally lower than incumbent's price in equilibrium ⇒ Both the incumbent and the entrant charge monopolistic price in equilibrium
    - A (conditional) smart contract allows the entrant to capture a larger share of producer surplus
  - By pricing in tokens, the incumbent can tap into new customers' demand ⇒ Will do it if the demand growth rate is sufficiently high
- This paper illustrates **benefits to new entrants of using "utility tokens" for product pricing** at the output market competition stage
  - In contrast to existing research, which focuses on benefits and costs of issuing "security tokens" at the pre-R&D stage
  - However, issuing tokens may lead to a de-facto reduction in competition, harming consumers