Economic Implications of Blockchain Platforms

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Abstract

In an economy with asymmetric information, the smart contract in the blockchain protocol mitigates uncertainty. Since, as a new trading platform, the blockchain triggers segmentation of market and differentiation of agents in both the sell and buy sides of the market, it reconfigures the asymmetric information and generates spreads in asset price and quality between itself and traditional platform. We show that marginal innovation and sophistication of the smart contract have non-monotonic effects on the trading value in the blockchain platform, its fundamental value, the price of cryptocurrency, and consumers’ welfare. Moreover, a blockchain manager who controls the level of the innovation of the smart contract has an incentive to keep it lower than the first best when the underlying information asymmetry is not severe, leading to welfare loss for consumers.

JEL codes: D47, D51, D53, G10, G20, L10

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1. Introduction

Since Bitcoin was proposed by Nakamoto (2008), the notion of the blockchain has gone viral as a new, innovative way to manage information. It provides a decentralized, public information management system in which data can be recorded as valid only if a consensus has been reached. Moreover, Ethereum, the second-largest blockchain, has invented a protocol to implement a smart contract—one that is executed automatically based on specified conditions without any centralized authorizations (Szabo, 1997). We can exploit this protocol to exchange assets, products, and information. For example, many blockchain-based trading platforms have been launched, such as those for foods (EY Advisory & Consulting, Walmart), jewelry (HyperLedger), arts and photography (Kodac), security (tZero), and cryptocurrency (Waves, IDEX, Steller, Oasis, OKEx, Cashaa, and more).

In spite of this growth, the academic research on these topics is still in its infancy. We contribute to the literature by proposing a simple yet intuitive theory that explores the economic implications of blockchain technology. In accordance with previous research (see the next subsection), our primary focus is on the blockchain as a new platform for exchanging goods and assets. Given that the technology aims to improve information management, we consider an asymmetric information problem regarding the assets traded. Moreover, since the blockchain works as a new platform and is operated in parallel with a traditional exchange with no blockchains, it has the features of a multi-platform economy with two-sided markets, as described in the field of industrial organization (IO). We investigate how innovation in blockchain technology affects the segmentation of the trading platforms, the price and quality of the assets traded, information asymmetry, and consumers’ welfare. We also define the fundamental values of the blockchain platform and its attached cryptocurrency.

The smart contract is one of the most innovative aspects of the blockchain system, which differentiates it from the traditional exchange protocol with cash or credit. In traditional exchange, there is no way to eliminate the asymmetric information a priori, and the possibilities of adverse selection and market breakdown are omnipresent. To mitigate this problem, a typical economy relies on intermediations by a third party, such as banks, insurance providers, and central securities depositories, to offload the risks. In contrast, a blockchain transaction is immune from information asymmetry due to the security mechanism hard-wired into the protocol. As discussed in Section 2., transaction information stored in the blockchain is protected from tampering, that is, rewriting the transaction record comes at a prohibitively large cost. Crucially, Ethereum allows the transactions to be executed based on sophisticated scripts; users can write a code on the blockchain that describes the specific conditions they wish them to fulfill. Hence, the transaction can be state contingent, and the validity of “state information” is highly credible. This highlights the difference of the blockchain protocol from credit as a record-keeping method, since the latter is not responsible for the actual transfer and quality of goods, while both of them are automatically guaranteed on Ethereum.

We consider non-atomic sellers and buyers who decide what type of transaction platform to use to exchange assets whose quality (high or low) is unknown to buyers. We define the smart contract in our economy by claiming that a transaction by means of the blockchain technology bears less information asymmetry. The traditional market (cash-market or C-market) cannot detect low-quality assets, and buyers face severe quality uncertainty. On the blockchain platform (B-market), in contrast, the low-quality assets can be detected and excluded before trading occurs with some probability $\theta$, which we call the security level (Appendix A provides a couple of examples as a micro-foundation for $\theta$). At first, we take $\theta$ as an exogenous parameter, whereas in Subsection 4.4.2. and onward, we study a manager of the blockchain platform who controls $\theta$. Our main focus is on how $\theta$ affects the activity of the entire economy.

As the literature on two-sided markets suggests, the first direct consequence of the emergence of the
blockchain platform (a positive $\theta$) is the differentiation and segmentation of both the sell and buy sides of the market. This segmentation is accompanied by endogenous spreads in the quality and price of assets between the blockchain and traditional platforms. Then, we find that marginal innovation in the security level $\theta$ has non-monotonic effects on the transaction value in the blockchain platform, the fundamental value of this platform, the price of cryptocurrency, and consumers’ welfare. That is, a more secure blockchain platform does not necessarily induce more active transactions and better allocation for consumers.

A higher $\theta$ directly improves the quality of assets supplied in the $B$-market, since the smart contract precludes a certain fraction of bad assets. In addition, quality in the $B$-market is endogenously amplified by the general equilibrium effect. The higher quality induces a higher price of the assets traded through the $B$-market due to a higher expected return. On the supply side, sellers of low-quality assets confront the price-liquidity (rejection) tradeoff. They can obtain a higher return from trading the asset in the blockchain platform, but at the risk of being rejected and ending up consuming their own low-quality asset. On the other hand, if a seller has a high-quality asset, the net return from selling it in the $B$-market monotonically increases as the bid price goes up with no fear of rejection. Thus, the reaction to innovation differs depending on the nature of the seller’s asset, endogenously boosting the flow of high-quality assets into the $B$-market.

On the demand side, whether the higher security attracts more buyers to the $B$-market depends on the relative rise in the assets’ quality versus the increase in the price, i.e., buyers face the traditional price-quality tradeoff. We show that the improvement in the quality is driven solely by the sell side’s behavior, while the price change is caused by the increase in the demand and decrease in the supply, which leads to a larger increase in the price than in the quality. As a result, a higher $\theta$ pushes the price up and reduces the transaction volume, making the $B$-market “an exclusive market for a high-quality but expensive asset.”

If the primitive asymmetric information is not severe, it is easier for buyers to give up the higher quality in the $B$-market and migrate to the $C$-market to save the price cost. This implies that a higher $\theta$ generates a larger decline in the transaction volume than the increase in the price, leading to less activity in the $B$-market as measured by the trading value.

To quantify the fundamental value of the blockchain itself, we also consider a blockchain manager who proposes an ex-ante contract that enables traders to use the platform for a fee. Access to the blockchain platform generates a strictly positive welfare gain for market participants, which makes traders willing to pay. This positive fee can be seen as the fundamental price of the blockchain technology, and we show that its behavior has the same implications as the trading value in the $B$-market and is non-monotonic in $\theta$. Therefore, our model implies that the sophistication of the blockchain, measured by a higher $\theta$, can reduce the technology’s value as a trading platform.

Based on this non-monotonicity, we discuss the optimal security level $\theta$ for the platform manager. As mentioned earlier, a higher $\theta$ can reduce the number of consumers who participate in the $B$-market, the trading value, and the aggregate welfare gain for consumers. This implies that the blockchain manager can charge only a small fee, since, ex-ante, each consumer expects that the gain from participating in the exclusive $B$-market is small. This gives the manager an incentive to keep $\theta$ lower than the first-best level for consumers ($\theta = 1$). In other words, she cares only about the transaction value in the $B$-market and does not reckon with the effect of $\theta$ on the activity in the $C$-market, making her underestimate the benefit of an increase in $\theta$.

This decline in the trading value and maximum possible fee tend to occur when the asymmetric information is not severe and migration is easier for consumers. In contrast to the conventional perspective, our results indicate that the government should intervene in the market to promote blockchain transactions when

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1 The “price of assets in the $j$-market” is valued in terms of cash, not cryptocurrency. Accordingly, we can see cryptocurrency as an asset, and its price is also valued in terms of cash.

2 This is consistent with the literature on strategic management (Teece, 1986; Brandenburger and Stuart Jr, 1996) arguing that a firm may not adopt innovation even though it improves consumers’ welfare.
an information problem is not severe, while it does not need to meddle when it is severe.

After a review of the related literature, Section 2 provides an overview of the technology of the blockchain and cryptocurrency. Section 3 introduces the theoretical environment, while Section 4 analyzes comparative statics to understand the effect of higher security in blockchain technology. In Section 5, we propose the empirical hypotheses, and Section 6 concludes the discussion.

1.1. Literature Review

The research on blockchain technology and cryptocurrencies (or FinTech, in general) is expanding (see Harvey [2016] for a comprehensive review). First, viewing the blockchain protocol as a new trading platform is widely accepted. Bartoletti and Pompianu (2017) provide empirical evidence for the usage of the blockchain and the smart contract as a platform. Chiu and Koeppl (2017, 2018) analyze the optimal design of the blockchain to guarantee “Delivery vs. Payment” by considering an economy with an intertemporal risk of settlement. Cong, Li and Wang (2018) develop a model in which the demand and price dynamics of tokens (cryptocurrency) are driven by the size of the blockchain as a platform and its trading needs.

The blockchain can affect consumers’ welfare through many channels. According to Cong and He (2017), its reduction of asymmetric information promotes the entrance of firms and improves consumer welfare, although its efficient record keeping makes it easier for firms to collude. Malinova and Park (2017) compare the possible degrees of transparency of the private blockchain and find that the most transparent setting maximizes consumers’ welfare at the risk of front-running.3 Khapko and Zoican (2016) focus on the optimal duration of the transactions under counterparty risk and search friction to show that the optimal implementation of settlement can improve welfare.4

Our model agrees with these studies on the fundamental effect of the blockchain: it reduces the transaction cost by mitigating informational problems. However, our economy, in which buyers face ex-ante quality uncertainty, highlights how the blockchain endogenously reconfigures information asymmetry via quality differentiation and platform segmentation—both of which are not analyzed in the literature—and how it affects the value of the blockchain platform and consumers’ welfare.

The second strand of the literature, which emerged from Akerlof (1970), examines adverse selection. Authors such as Kim (2012), Guerrieri and Shimer (2014), and Chang (2017) show that market segmentation leads to quality differences across markets.5 We see the blockchain as a new platform for trade, which exists alongside the traditional cash market, and analyze the effect of segmentation in the context of FinTech. Unlike the literature, in which the markets are homogeneous per se, our analyses propose that the different structure of one market (e.g., the degree of security) affects the entire economy. Also, these works do not investigate the manager who optimally chooses the structure of her platform.

Our paper is also related to the literature in IO that analyzes endogenous market structures and platform competition with two-sided markets. The market segmentation and differentiation of agents have been analyzed by Foucault and Parlour (2004), Rochet and Tirole (2006), Damiano and Hao (2008), Ambrus and Argenziano (2009), and Gabszewicz and Wauthy (2014), although they do not study asymmetric information in the form of asset quality uncertainty. Yanelle (1997) and Halaburda and Yehezkel (2013) consider competing platforms under asymmetric information, though they focus on the information asymmetry between the platform

3Users of blockchains can make the network private and limit information transactions within a firm or a group of firms. This category of platforms is called a “closed-type” or “permissioned” blockchain. The public blockchain, in contrast, is called “open-type” or “permissionless.”

4The feasibility of the blockchain implementation is another hot topic. For example, Biais et al. (2018) consider “the folk theorem” of the blockchain as a coordination game, and Aune, O’Hara and Slama (2017) propose the hash-based protocol to address the issue that stems from miners’ incentive to delay the publication of the block.

5Another dimension of segmentation is time, i.e., participants can decide when to trade, as analyzed by Fuchs, Green and Papanikolaou (2016), Asriyan, Fuchs and Green (2017), and Fuchs and Skrzypacz (2017).
and agents. In line with these works, our platform manager controls the asymmetric information between agents, while she does not incorporate some types of externality due to the general equilibrium effects.\footnote{More broadly, a different security level of the blockchain $\theta$ in a market with asymmetric information can be interpreted as government intervention, such as the purchase of assets on OTC after the recent financial crisis. Most models of government intervention do not consider the interaction of segmented markets. See, for example, Philippon and Skreta (2012), Tirole (2012), and Chiu and Koeppl (2016).}

Finally, the idea of the blockchain as a record-keeping method that competes with the traditional cash is reminiscent of the concept of “money as memory.” How money and credit can substitute for each other or coexist has been explored by Kocherlakota (1998), Kocherlakota and Wallace (1998), Lagos and Wright (2005), Rocheteau and Wright (2005), Camera and Li (2008), and Gu, Mattesini and Wright (2014). However, credit as an alternative payment method does not affect the quality of the assets traded because it remains a record of a debtor, but not of the assets’ quality. Thus, the market segmentation in the literature is intertemporal (day and night): a decentralized market comes first to make some credit, and a centralized one comes afterwards to settle repayment. As some evidence in Section 5. suggests, however, the blockchain platform triggers market segmentation even in a static environment by keeping a record of assets’ quality, making transactions contingent on it, and differentiating both buyers and sellers.

2. Technology Overview: Blockchain Protocol

The blockchain can be seen as a novel way of managing and tracking transaction information. Participants in a transaction (say, sellers and buyers) possess private information about their state—how much bitcoin they own or have already spent, the quality of the products they sell, and so on. In the traditional world, we typically maintain a ledger that records participants’ state information in a centralized manner, e.g., there is a bank as an intermediary. Bilateral transactions with no intermediations by a credible third party incur the risk of adverse selection due to asymmetric information or settlement risk.

In contrast, on the blockchain platform, the ledger is not held by a particular entity, but is distributed across all participants in the network. The distributed ledger system requires the information about the state of the economy to be a consensus among all the participants. This highlights its first difference from traditional transactions, in which only a centralized intermediary keeps track of the state information.

Moreover, Ethereum allows complex scripts to be written to describe the conditions under which the information is verified and recorded, which implies that a transaction takes place only if the conditions in the code are fulfilled (i.e., it is state contingent). This is the crucial aspect that differentiates the blockchain from the credit system (or credit cards) as a record-keeping method.\footnote{A warranty is an example of a similar system to the blockchain. Even though warranties guarantee the quality of products, they have two main differences. First, warranties are provided and executed only if the product is transferred and the ex-post quality is verified, while the smart contract transfers the product only if the quality is guaranteed. Thus, they differ in which aspect of the transaction, the quality or the transfer of products, is contingent on the other. Second, the execution of warranties comes at a significant cost for consumers, while the smart contract never requires consumers to take the cost because making a transaction serves as a quality certification. See, for example Lehmann and Ostlund (1974) and Palfrey and Romer (1983).}

In general, it is extremely difficult for one member of the network to overturn the consensus. In the case of Bitcoin, for example, system managers called miners leverage their computing power to solve a time-consuming cryptographic problem. This process is called “proof of work,” and the miner who performs it fastest is entitled to add a new block to the chain. Therefore, if a malicious agent attempts to add fraudulent information to the transaction history, she must outpace all miners in the network, which requires prohibitively high computing power.\footnote{There are several ways to reach a consensus, and different blockchains adopt different processes. Chiu and Koeppl (2017) provide a theoretical comparison of the efficiency of these methods.}

Once a set of transaction information forms a block, it is encrypted by a hash function and passed to the next block to create a chain of blocks. The output of the hash function becomes different if one entity of input
is different. Thus, revising a piece of information in a chain requires the revision of all of the subsequent information in the blockchain. As a result, any attempts to benefit from modifying the existing information is virtually impossible. That is to say, only relevant information can be added to the blockchain, and it is free from tampering.

3. Theoretical Framework

Consider an economy with segmented markets that operate at \( t = 0 \) and \( 1 \). There is a continuum of risk-neutral buyers (consumers) and sellers (producers), both characterized by the private value \( \alpha \in [0, 1] \). \( \alpha \) has a cumulative measure \( F \), which will be assumed to be uniform.\(^9\) At date \( t = 0 \), each buyer is endowed with a certain amount of cash \( w \), draws \( \alpha \), and partakes in markets to buy an asset.

On the sell side, each seller is endowed with a unit asset with a stochastic quality \( q \), which is either high, \( q = H \), or low, \( q = L \), with \( \Pr(q = H) = \pi \in (0, 1) \) and independent of \( \alpha \). By the law of large numbers, the economy-wide fraction of high-quality assets is \( \pi \), and that of low-quality assets is \( 1 - \pi \). Also, risk-free savings with a zero interest return are available.

For both sellers and buyers with a private value \( \alpha \), the asset yields the following (per capita) utility at date \( t = 1 \):

\[
y(\alpha) = \begin{cases} 
\alpha & \text{if } q = H \\
\phi \alpha & \text{if } q = L 
\end{cases}
\]

\( \phi \in (0, 1) \) is the primitive quality difference. If the asset is low-quality, agents obtain only \( \phi \) fraction of the utility. Following the literature on market microstructure (such as Glosten and Milgrom, 1985), agents can trade and hold, at most, one unit of asset and cannot short-sale.

3.1. Market Structure

There are two trading platforms with different mediums of exchange. One is the blockchain with cryptocurrency and the other is the traditional market with fiat money. We give transactions via the blockchain platform an index \( j = B \) (blockchain) and those with fiat money an index \( j = C \) (cash).

**Smart Contract**

To distinguish transactions via the blockchain from those through the cash market, we define the *smart contract* in our model as follows.

**Definition 1.** \( \theta \) fraction of low-quality assets that sellers intend to sell in the \( B \)-market are detected and rejected by the blockchain mechanism.

The parameter \( \theta \) is called the “security level” of the blockchain platform. We provide the motivating example and micro-foundation of \( \theta \) in Appendix A. The interpretation of \( \theta \) can differ depending on the context in which we apply this model. For instance, if the traded asset is the cryptocurrency itself, such as Bitcoin, \( \theta \) is the probability that the mechanism will preclude attempted “double spending.” If the traded asset is consumption goods, as in the wine blockchain, \( \theta \) captures how intensively the contracts are made contingent

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\(^9\)For example, if a state of the transaction up to \( t \) is denoted by \( s^t = (s_t, \cdots, s_0) \), a block at \( t \) records the information of transactions at \( t \) and the encrypted historical states, \( S_t = (s_t, h(s^t)) \), where \( h \) is a hash function. Now, the next block at \( t + 1 \) records \( S_{t+1} = (s_{t+1}, h(S_t)) \), and so on. If an agent wants to rewrite the past state \( s_k \) to \( s'_k \), then she must change all the blocks \( S_k, S_{k+1}, \cdots, S_t \) because this attempt induces the change in \( S_k \) which triggers a change in \( S_{k+1} \) because \( h(S_k) \) with \( s_k \) is not identical to that with \( s'_k \) and so on.

\(^{10}\)Imposing the same \( F \) on both sellers’ and buyers’ \( \alpha \) is for tractability and is not essential in our analyses.
throughout the intermediations between producers and consumers. At first, we take this value as given for participants in the market. Later, in Subsection 4.4.2, and on, we study a case wherein a manager of the blockchain can control this security level.

Moreover, to motivate agents to hold cryptocurrency, we introduce the following restriction:

**Assumption 1.** To buy \( k_B \) amount of assets at price \( P_B \) (in terms of cash) in the \( B \)-market, a buyer must hold \( P_B k_B / Q \) of cryptocurrency, where \( Q \) is the price of cryptocurrency in terms of cash (see the budget constraint [1]).

This assumption comes from the fact that the endowment is given by cash. We call it the “cryptocurrency in advance” (CIA) constraint in our model, and Schilling and Uhlig (2018) consider a similar formulation. It will be clear that the demand and pricing for cryptocurrency are determined mostly outside of the asset trading market. Therefore, by removing Assumption 1 and imposing it on sellers’ behavior, we can still analyze the other class of cryptocurrency platforms, such as a part of Ethereum, in which the sellers must have cryptocurrency to verify their authenticity. Also, we show that the fundamental price of blockchain technology can be characterized even without Assumption 1.

### 3.2. Optimal Behavior of Buyers

A buyer with type \( \alpha \) maximizes her expected consumption at \( t = 1 \), \( V(\alpha) = E[c | \alpha] \), under the following budget constraints:

\[
    w \geq P_C k_C + Qb + s, \quad \frac{Q}{P_B} b \geq k_B, \quad (1)
\]

\[
    c = y_C(\alpha) k_C + y_B(\alpha) k_B + s.
\]

\( k_j \) and \( P_j \) represent the demand and price of the asset at market \( j \), \( Q \) is the price of cryptocurrency, and \( b \) is the demand (quantity) for cryptocurrency. All prices are valued in terms of cash. Thus, the price of assets traded in the \( B \)-market in terms of cryptocurrency is \( P_B / Q \). A risk-free saving option is denoted by \( s \). The definition of \( y_j(\alpha) \) is given by (2) below.

The constraints in the first line imply that the buyer allocates her cash endowment to the purchase of the asset in the \( C \)-market and cryptocurrency, and the latter is used to buy the asset in the \( B \)-market. The purchase amount in the \( B \)-market is limited by her holdings of cryptocurrency, as Assumption 1 suggests. As well, the agent can stay inactive to get zero utility from her assets. The second line shows the consumption level, in which, for \( j \in \{ B, C \} \),

\[
    y_j(\alpha) \equiv \tilde{\pi}_j(\alpha) \equiv [\pi_j + (1 - \pi_j) \phi] a, \quad (2)
\]

\[
    \pi_j \equiv \Pr(q = H \text{ in Market-}j). \quad (3)
\]

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11 Another interpretation of \( \theta \) is in light of consensus quality in Cong and He (2017). Although the distributed ledger makes a consensus on the state close to perfect by aggregating the reports by system keepers, there is still noise and bias. We take a large \( \theta \) as a precise consensus. Also, Kroll, Davey and Felten (2013) consider a risk that the distributed ledger system goes wrong by group’s attempt to make a consensus. It is also shown by Biais et al. (2018) that a folk of a chain generates two (or more) different consensuses. We capture these events by \( \theta < 1 \).

12 We can incorporate insurance or third-party institutions that reduce the risk of lemons in the \( C \)-market, which typically exist in the real economy. One possible way to describe them is by introducing a rejection probability \( \eta_C \) in the \( C \)-market as well. A more parsimonious way, which we follow, is to think of \( 1 - \pi \) as the fraction of low-quality assets that stay in the economy even after we ask third-party institutions to reject them, i.e., the existing insurance cannot cover all the assets.

13 As explained in the introduction, this assumption captures the class of cryptocurrencies that is used as a means of exchange in the blockchain trading platform. The analyses in Subsection 4.4. provide a measure of the fundamental value of the blockchain, instead of the value of the cryptocurrency, and hence does not need this assumption regarding CIA.
Hence, \( y_j \) represents the expected private return adjusted by the risk of lemons in market \( j \), which is denoted by \( 1 - \pi_j \).

Because of the risk neutrality and linearity of \( y \), splitting order into two markets is not optimal.\(^{14}\) Thus, the demand always hits its upper limit (\( k_j = 1 \)), and the CIA constraint is binding. The expected return from purchasing assets in each market \((V_B, V_C)\) and that from staying inactive \((V_0)\) are given by

\[
V_j(\alpha) = \begin{cases} 
\pi_j \alpha - P_j & \text{if } j \in \{B, C\} \\
0 & \text{if } j = 0.
\end{cases}
\]

We subtract \( w \) from the equations above because it does not affect the equilibrium behavior.

To solve the venue-choice problem, we guess the following\(^{15}\):

\[
\frac{P_B}{\pi_B} > \frac{P_C}{\pi_C}, \pi_B > \pi_C,
\]

which will be shown to be a unique equilibrium. Intuitively, \( P_j / \pi_j \) is a normalized price and represents the cutoff of \( \alpha \) that generates indifference between buying in the \( j \)-market and staying inactive.\(^{16}\) It indicates a positive measure of traders with relatively high (resp. low) \( \alpha \) who wish to go to the \( B \)-market (resp. \( C \)-market).\(^{17}\) Indeed, under (4), the optimal behavior of buyers with type \( \alpha \) is determined by the cutoff \( \alpha^* \) such that

\[
\alpha^* \equiv \frac{P_B - P_C}{\pi_B - \pi_C}.
\]

Figure 1 plots returns, \( V_\alpha \), against \( \alpha \) and shows the cutoffs for the optimal behavior. Namely, it is optimal for type \( \alpha \) buyers to (i) buy one unit of the asset in the \( B \)-market if \( \alpha \geq \alpha^* \), (ii) in the \( C \)-market if \( \alpha \in \left(\frac{P_C}{\pi_C}, \alpha^*\right)\), and (iii) stay inactive otherwise.

Intuitively, each buyer faces a price-quality tradeoff, \( i.e. \), the \( B \)-market provides higher quality and expected returns, but charges a higher price. Note that the gain from a higher \( \pi_j \) is multiplied by \( \alpha \), while the cost is constantly \( P_j \). Hence, the \( B \)-market looks more attractive for high-\( \alpha \) buyers.

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\(^{14}\) Only the buyers on the threshold (defined below) can split the order, but we simplify our discussion by assuming a tie-breaking rule that indifferent agents trade in the \( B \)-market.

\(^{15}\) See Gabszewicz and Wauthy (2014) for a similar structure, in which they state these as assumptions, while we derive them endogenously.

\(^{16}\) Buyers’ behavior can be seen as the model of vertical differentiation, such as the one provided in Chapter 2 of Tirole (1988).

\(^{17}\) If (4) does not hold, the \( B \)-market becomes too attractive to guarantee the coexistence.
By aggregating along $\alpha$, the total demand in each market is

$$K_j^D = \begin{cases} 1 - F(\alpha^*) & \text{for } j = B, \\ F(\alpha^*) - F\left(\frac{p_j}{\pi_j} \right) & \text{for } j = C. \end{cases}$$ (5)

The uniform $F$ allows us to derive inverse demand functions: \( P_j = \begin{cases} \left(\frac{1}{\pi_C} + \frac{1}{\Delta \pi} \right)^{-1} \left(\frac{p_j}{\Delta \pi} - K_j^D \right) & \text{for } j = C \\ p_C + \Delta \pi (1 - K_j^D) & \text{for } j = B, \end{cases} \) (6)

with $\Delta \pi \equiv \pi_B - \pi_C$. Note that plugging in the aggregate supply $K_j^S$—which will be derived in the next section—yields the equilibrium prices.

The price in one market affects the price in the other, and the quality difference, $\Delta \pi$, influences the prices in the following way:

**Lemma 1.** With a fixed supply, a larger quality difference ($\Delta \pi$) induces more traders to migrate from the $C$-market to the $B$-market, leading to a lower $p_C$ and higher $p_B$.

From the second equation, the price spread, $\Delta P \equiv p_B - p_C$, stems from the quality difference. This can be seen as a premium: The asset in the $B$-market obtains a higher valuation than the one in the $C$-market through its higher quality, $\Delta \pi$. We derive the quality difference from supply-side behavior in the next subsection.

### 3.3. Optimal Behavior of Sellers: Endogenous Quality

As the literature on adverse selection assumes, each seller knows the quality of her asset.\(^{19}\) Also, note that each seller does not engage in strategic trading: the signaling effect of venue choice is shunted aside because each trader is non-atomic. Instead, the sell-side selection (screening) occurs due to $\theta > 0$, even in the competitive equilibrium.\(^{20}\)

#### 3.3.1. Low-Quality Sellers

First, we consider the optimal strategy of sellers with low-quality assets ($L$-type sellers). If a trader sells the asset in the $B$-market, the expected return is

$$W_B^L = (1 - \theta) p_B + \theta \phi \alpha. \quad (7)$$

The first term represents the case where the transaction avoids rejection, while the second is the case where the asset is rejected by the blockchain. In the latter case, the trader must use the asset to get $\phi \alpha$.\(^{21}\) On the other

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\(^{18}\)As for the form of $F$, the uniform assumption is restrictive in this model. The equilibrium is driven by the migration behavior of agents. For example, if we make $F$ bimodal, or if we only have two types of $a$, in the extremum case, the effect through the migration is muted. By assuming uniformity, the fundamental effect of the blockchain platform and market structure are not altered by this slope-effect (or drastic change in the extensive margin) of migration. This is the problem that commonly arises in the model of segmented markets in which heterogeneous traders decide in which one to participate. See, for example, Zhu (2014) for a similar discussion.

\(^{19}\)This structure can be generalized by assuming that the seller is informed with probability $\lambda$ and uninformed with probability $1 - \lambda$. An informed seller knows a specific characteristic of the asset and can distinguish lemons, while an uninformed agent cannot. We provide the analyses in the generalized case with $\lambda \in (0, 1)$ in Appendix B.

\(^{20}\)Notice that, by setting the model in this way, we also implicitly exclude the possibility of collusion by sellers as in Cong and He (2017). Since sellers are non-atomic, they expect that their behavior does not affect the market prices, quantity, or quality.

\(^{21}\)The alternative assumption is allowing rejected traders to conduct "order routing." A trader can first try to sell in the $B$-market and, if rejected, can submit a sell order in the $C$-market. We can show that this alternative assumption does not change our main results, including propositions 1, 2, and 4, though the equilibrium conditions are slightly modified. The results are available upon request.
hand, if she sells it in the C-market, the return is \( W_C^L = P_C \), while the return from staying inactive is \( W_0^L = \phi \alpha \). See the left-hand panel of Figure 2 for a diagram of these value functions.

![Figure 2: Returns for Sellers](image)

By comparing these three returns as functions of \( \alpha \) under (4), we see that the optimal strategy is to (i) stay inactive if \( \alpha > P_B \) and (ii) sell it in the C-market if \( \alpha \in (\alpha_I, P_B / \phi) \), and (iii) sell in the B-market if \( \alpha \leq \alpha_I \), where

\[
\alpha_I = \max \left\{ \frac{P_C - (1 - \theta) P_B}{\phi \theta}, 0 \right\}
\]

is the cutoff that separates sellers into the B- and C-markets.

When it is strictly positive, the cutoff \( \alpha_I \) is increasing in \( \theta \), decreasing in \( \phi \), and increasing in the expected price difference (numerator of \( \alpha_I \)). Given the prices, an increase in \( \theta \) makes sellers who traded in the B-market migrate to the C-market because a higher rejection probability lowers their expected profit. On the other hand, a higher \( \phi \) increases the continuation value and the profit from selling in the B-market, causing marginal sellers to switch to this platform. Finally, a larger difference in the expected prices, \( P_C - (1 - \theta) P_B \), makes the C-market more attractive.

High-\( \alpha \) sellers are more likely to trade lemons in the B-market, while low-\( \alpha \) sellers tend to prefer the C-market due to the price-liquidity tradeoff, i.e., the B-market provides a higher selling price, but at the risk of rejection. High-\( \alpha \) sellers do not care about the lower execution probability in the B-market because they can obtain a high value of \( \phi \alpha \) even if the selling order is rejected, while the opposite is true for their low-\( \alpha \) counterparts.

### 3.3.2. High-Quality Sellers

For a seller with a high-quality asset (\( H \)-type seller), the return from trading in the C-market, B-market, and not trading are given by\(^{22}\)

\[
W_J^H = \begin{cases} 
  P_j & \text{for } j = B, C, \\
  \alpha & \text{if } j = 0.
\end{cases}
\]

Under the guess (4), the optimal behavior is to (i) stay inactive if \( \alpha > P_B \) and (ii) sell it in the B-market if \( \alpha \leq P_B \). The right-hand panel of Figure 2 shows this comparison.

\(^{22}\)More precisely, a seller who sells in the B-market obtains \( P_B / Q \) of cryptocurrency, which amounts to \( P_B \) in terms of cash value. We implicitly assume that sellers have access to a dynamic market for cryptocurrency, in which they can trade it for fiat money at the same exchange rate \( Q \) over time. This assumption is motivated by the overlapping generations of traders. The structure of these generations is identical over time, and buyers in their young period arrive at the markets and demand cryptocurrency as a means of exchange. Conversely, older sellers are ready to trade their cryptocurrency for fiat money.
Therefore, the amount of assets that sellers intend to sell in each market is

\[ S_B = \pi F(P_B) + (1 - \pi) \left[ F\left(\frac{P_B}{\phi}\right) - F(a_I) \right], \tag{9} \]

\[ S_C = (1-\pi)F(a_I). \tag{10} \]

In (9), the first term is the supply from \(H\)-type sellers, and the second is that from \(L\)-type sellers. (10) only consists of \(L\)-type selling behavior. As suggested by the literature on adverse selection with segmented markets (Chen, 2012; Kim, 2012; Guerrieri and Shimer, 2014), a market with a low (high) price and deeper (shallower) liquidity tends to attract low-quality (high-quality) assets because the different prices and liquidity can work as a screening device.

Since the blockchain technology weeds out \(\theta\) fraction of the lemons from the \(B\)-market, the supply functions are given by

\[ K^S_B = \pi F(P_B) + (1-\pi)(1-\theta)\left[ F\left(\frac{P_B}{\phi}\right) - F(a_I) \right], \tag{11} \]

while, in the \(C\)-market, all of the selling attempts are accomplished, \(K^S_C = S_C\). As a result, the average quality in each market is derived as follows:

**Lemma 2.** Endogenous market qualities are given by

\[ \pi_j = \begin{cases} \pi F(P_B), & j = B \\ 0, & j = C \end{cases}, \tag{12} \]

Note that all of the high-quality assets go to the \(B\)-market since it provides a better price. In other words, all of the assets traded in the \(C\)-market are of low quality. This arises from the information structure of sellers (i.e., they all know the quality of their assets). In the real economy, it is not natural to claim that the \(C\)-market contains only low-quality assets. Thus, in Appendix B, we redefine the equilibrium with uninformed sellers to show that a more general information structure provides \(0 < \pi_C < \pi_B < 1\) in the equilibrium, while we stick to our current formulation in the main model to extract clear intuitions.

3.4. Equilibrium Spreads

We can define the general equilibrium as follows:

**Definition 2.** The general equilibrium is defined by the price, quality, and quantity, \((Q, \{P_j, \pi_j, K_j\}_{j \in \{C,B\}})\), that clear the markets \(K^S_j = K^D_j\) with the following equations (under the normalization of \(B_S = 1\)):

\[ K^S_C = (1-\pi)\alpha_I, K^S_B = \pi P_B + (1-\pi)(1-\theta)\left(\frac{P_B}{\phi} - a_I \right), \tag{13} \]

\[ K^D_B = 1 - \frac{P_B - P_C}{\pi_B - \phi}, K^D_C = \frac{P_B - P_C}{\pi_B - \phi} - \frac{P_C}{\phi}, \]

\[ \pi_B = \frac{\pi P_B}{K_B}, Q = P_B K_B^i. \]

The last equation is the clearing condition for the cryptocurrency market.

We can quantify the spreads in the price and quality between the two markets (see Appendix C1. for the proofs).

**Proposition 1.** The blockchain market achieves a higher quality than the cash market, i.e., \(\pi_B > \pi_C\).
Proposition 1 has direct implications for the prices. That is, the positive spread in the quality, $\Delta \pi > 0$, results in a higher price in the $B$-market as well.

**Proposition 2.** The price of assets traded in the $B$-market is higher than that in the traditional $C$-market, that is, $P_B > P_C$.

This conclusion is consistent with the findings on the wine blockchain by the EY Advisory (see Section 5.), in which wines sold on the blockchain platform attain a higher price.

Note that a higher $\theta$ affects $\pi_B$ via two channels. First, it exogenously precludes $\theta$ fraction of the lemons as the second term in (13). Second, it generates the endogenous sorting of low-quality assets which manifests in the change in the cutoff $\alpha$ caused by the fluctuation of $P_j$. This happens even if the sellers do not trade strategically. Rather, the sell-side selection is a consequence of the purely competitive tradeoff between the higher equilibrium price in the $B$-market and detection risk. Due to its higher continuation values, high-quality assets tend to cluster in the $B$-market, while low-quality assets cluster in the $C$-market to avoid being rejected. This mechanism generates a higher quality and price in the $B$-market (spreads), which are self-sustaining in the equilibrium.\textsuperscript{23}

4. Comparative Statics: The Effect of Security Improvement

For a technical reason, assume that the following condition holds:\textsuperscript{24} $\pi(1 - \pi)(1 - \phi) < 1/4$.

4.1. Cash-Market Breakdown

Our first result regarding blockchain security seems rather drastic: the existence of this platform can completely destroy the activity of the cash market when the security level $\theta$ is sufficiently low. This appears counterintuitive given the literature on “money versus credit,” which argues that a more sophisticated record-keeping system makes cash inessential. Our result depends on whether $\theta$ becomes too low to sustain $\alpha_I = P_C - (1 - \theta)P_B > 0$.\textsuperscript{25}

**Lemma 3.** Let $\theta_0$ be the smaller solution of $\theta^2(1 - \pi) - \theta + \pi(1 - \phi) = 0$. (i) $\alpha_I$ is positive if and only if $\theta > \theta_0$. (ii) $\theta_0$ is decreasing in $\phi$ and $\pi$.

**Proof.** See Appendix C2. for the statement (i). (ii) follows immediately from the definition of $\theta_0$. \hfill $\square$

Recall that $\alpha_I$ is the cutoff for $L$-type sellers in the $B$-market ($\alpha \geq \alpha_I$) or in the $C$-market ($\alpha < \alpha_I$). Therefore, Lemma 3 and (13) imply the following:

**Proposition 3.** The $C$-market shuts down, $K_C = 0$, when $\theta$ is smaller than $\theta_0$.

We denote the region $\Theta_{NC} \equiv (0, \theta_0]$ as the no $C$-market region. The result comes from the supply side. Remember that only $L$-type sellers trade their assets in the $C$-market. They wish to sell the asset at a higher price $P_B$, but they fear rejection. $\theta < \theta_0$ makes the rejection risk sufficiently small that the price improvement in the $B$-market becomes dominant. As a result, all the sellers migrate out of the $C$-market and try to sell in the $B$-market. Of course, this induces a higher $P_C$, but it is bounded and cannot explode due to the existence

\textsuperscript{23}The economy is not continuous at $\theta = 0$. When we make $\theta \searrow 0$, it converges to the segmented markets economy with two homogeneous markets, which is different from an economy with only one (the $C$-market). For this reason, we do not compare the single-market economy with the segmented economy. Rather, we focus on the comparative statics in the economy with segmented markets.

\textsuperscript{24}This condition guarantees that the economy has both cases of $\alpha_I > 0$ and $\alpha_I = 0$.

\textsuperscript{25}The term “cash-market breakdown” implies that all transactions that do not go through the blockchain disappear, but it does not intend to indicate the disappearance of cash due to digital currency with no blockchain foundation, such as PayPal.
of outside options (buying in the B-market or staying inactive). Also, the higher share of H assets in the B-market always makes \( P_B > P_C \) even at the limit of \( K_S^C = 0 \), making the shutdown of the C-market an equilibrium outcome.

We can determine the situations in which the C-market tends to be eliminated.

**Corollary 1.** A smaller \( \phi \) and \( \pi \) make the cash-market breakdown more likely, i.e., they make \( \Theta_{NC} \) larger.

**Proof.** Immediate from Lemma 3. \( \square \)

This result should also be intuitive if we recall that the critical \( \theta \) is expressed as \( \theta_0 = \frac{P_B - P_C}{P_B} \). The lower \( \phi \) and \( \pi \) mean that the underlying asymmetric information is severe, and both make buyers more eager to trade in the B-market, leading to a larger spread, \( P_B - P_C \). Then, sellers of low-quality assets are more willing to sell in the B-market and are likely to abandon the traditional cash market.\(^{26}\)

Of course, it is not realistic to anticipate that the real-world cash market will completely break down—we do not believe that all grocery stores will use the blockchain to track information for all products. However, our discussions can be viewed as the model of an exchange market for a particular class of assets (e.g., wine, diamonds, art, and so on), for which the dominance of the blockchain platform can be more believable. This also has implications for international trade, as transactions with a country that supplies an ambiguous quality of goods would be completely done through the blockchain.\(^{27}\)

### 4.2. Coexistence of Two Markets

In the following subsections, we let \( \theta \) be sufficiently high, as we are interested in the interaction of two markets.\(^{28}\) We first investigate how \( P_B \) and \( \pi_B \) are differently affected by \( \theta \).

**Proposition 4.** (i) The segmented-markets economy admits a unique solution in which (ii) \( \frac{dP_B}{d\theta} > 0, \frac{d\pi_B}{d\theta} > 0, \frac{dP_C}{d\theta} < 0, \) and \( \frac{dK_S^B}{d\theta} < 0 \). Moreover, (iii) the price spread widens more than the quality spread, i.e., \( \frac{\Delta P}{d\theta} > \frac{\Delta \pi}{d\theta} \).

**Proof.** See Appendix C3.. \( \square \)

Consider an increase in \( \theta \). The supply of high-quality assets is not directly affected, as the first term of \( K_S^B \) in (13) suggests. On the other hand, with a fixed \( P_B \), a higher \( \theta \) reduces \( K_S^B \) by detecting and sweeping out low-quality assets (the supply-side effect). Also, this improves the B-market’s quality, making participants more willing to buy in B-market, which increases \( K_D^B \) (the demand-side effect).

How does \( P_B \) change compared to the quality, \( \pi_B \)? The small supply and strong demand pressure both work to increase the price, i.e., it is pushed up by both the demand- and supply-side effects. On the other hand, the quality improvement is linked only with the decline in the supply. Crucially, this implies that the growth in the price is larger than the quality improvement, making the trading demand in B-market smaller.

This result has direct implications for the next results.

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\(^{26}\) Technically, we can avoid this by considering the general model with \( \lambda < 1 \), by restricting our focus on \( \theta \geq \theta_0 \), and by modifying the model according to the discussion in note 21.

\(^{27}\) Proposition 3 and Corollary 1 indicate that the shutdown occurs when (i) the introduced blockchain is immature in the sense of \( \theta \leq \theta_0 \), and (ii) agents suffers from severe asymmetric information. If we consider the micro-foundation of \( \theta \) in Appendix A, situation (i) can happen when the total number of intermediations between producers and buyers is large and covering all the steps using blockchain transactions is more difficult, as exemplified by international trade in the real world. Note that a longer intermediation chain also induces more severe information asymmetry, which implies that (i) and (ii) may ensure simultaneously.

\(^{28}\) We believe that a sufficiently high \( \theta \) that sustains the coexisting B- and C-markets is realistic given the discussion in the introduction. Arguments for \( \theta \leq \theta_0 \) are provided in Appendix C2.
4.3. Non-Monotonic Effects of Blockchain Sophistication

Our primary concern is whether the sophistication of the blockchain, measured by $\theta$, increases the transaction value in the platform, the price of cryptocurrency, the value of the blockchain itself, and consumers’ welfare. It turns out that a rise in $\theta$ has non-monotonic effects on these variables. Specifically, a higher $\theta$ is more likely to lower these variables when information asymmetry is not severe, or the level of $\theta$ is sufficiently small.

First, we formally state the results regarding the trading value and $Q$ in the sequel. We will offer intuitions and key mechanisms behind the results when we investigate the value of the blockchain and consumers’ welfare in the next subsection, because all of these variables are driven by the same factors.

4.3.1. Trading Value and the Price of Cryptocurrency

The market clearing condition gives $Q = P_B \int k_B \alpha \, dF(\alpha) = P_B K_B$ (with $B_S = 1$, which makes no difference in our analyses). Let $\phi_1 = \frac{2 - \pi}{3 - \pi}$, and $\phi_0 (< \phi_1)$ be the unique solution of (38) in Appendix C3..

Proposition 5. (i) If $\phi < \phi_0$, $Q$ and $P_B K_B$ are monotonically increasing in $\theta$. (ii) If $\phi_0 \leq \phi < \phi_1$, $Q$ and $P_B K_B$ are U-shaped, and there is $\theta^*$ s.t.,

$$\frac{dQ}{d\theta} = \frac{dP_B K_B}{d\theta} \leq 0 \iff \theta \leq \theta^*.$$

(iii) If $\phi_1 \leq \phi \leq 1$, $Q$ and $P_B K_B$ are monotonically decreasing in $\theta$.

Proof. See Appendix C3.. □

The proposition indicates that the trading value and the price of cryptocurrency exhibit a non-monotonic reaction to the sophistication of the blockchain technology.

This finding differentiates our theory from the literature on money versus credit, in which the increase in record-keeping ability tends to make cash inessential. As we will see in the next subsection, endogenous price and quality spreads, which are absent in the literature, are the key factors that prompt this result.

4.4. Fundamental Value of the Blockchain and Welfare Impact

In this subsection, we calculate the aggregate welfare of buyers (see Appendix D3. for sellers’ welfare), as well as the welfare gain from access to the blockchain platform.29

4.4.1. Buyers’ Welfare

We define the aggregate welfare of buyers by integrating the gain from trade (we ignore the common constant endowment $w$):

$$v_B = \int_{\alpha^*}^{\alpha^*} (\hat{\pi}_B \alpha - P_B) \, dF(\alpha) + \int_{P_C/\phi}^{\alpha^*} (\phi \alpha - P_C) \, dF$$

$$= \int_{\alpha^*}^{\alpha^*} (\hat{\pi}_B \alpha - \Delta P) \, dF + \int_{P_C/\phi}^{\alpha^*} (\phi \alpha - P_C) \, dF$$

In equation (14), the first term is the welfare of buyers who purchase in the $B$-market, and the second encompasses those who purchase in the $C$-market. This can be rewritten by using “welfare gain” and “reservation welfare” as in (15). The second term of (15) represents the welfare of all the active buyers from purchasing in

29 Technically, as the CIA constraint always binds, the welfare comparison does not hinge on the existence of cryptocurrency. More generally, the equilibrium variables with and without the CIA constraint are identical except for the formula for $Q$ because of the “monetary neutrality” of cryptocurrency.
the C-market, i.e., the reservation welfare when agents can use only this venue. The first term of (15) is the gain (increment) in welfare that stems from changing the trading platform from C to B, which only $\alpha \geq \alpha^*$ agents attempt to do. Interestingly, the welfare gain is co-linear with the trading value in the B-market in the benchmark model (see Appendix D1.). If the blockchain platform has cryptocurrency, it further implies that the welfare gain is measured by $Q$. The effect of $\theta$ on $v_B$ is analyzed later.

### 4.4.2. Fundamental Value of the Blockchain Technology

The first term of equation (15) shows that access to the blockchain technology attains a positive fundamental price. To see this, we introduce a monopolistic blockchain manager who maintains the platform and determines the level of $\theta$. The existence of this type of agent is realistic: even though the distributed ledger is managed by the participants of the network, there is an institution that provides the exchange platform itself.\(^{30}\)

We discuss the buy-side problem by assuming that consumers must pay a fee to use the blockchain.\(^{31}\) Let us introduce a pre-trade period $t = -1$ and suppose that a randomly picked buyer is approached by the blockchain manager (called the “manager,” hereafter), who charges a fee $f_B$ for access to the B-market before the type $\alpha$ is drawn at $t = 0$.\(^{32}\) Note that the behavior of this particular agent does not affect the expected market result because she is non-atomic. Also, there is no bargaining, the offer is one shot, and take-it-or-leave-it.

If the buyer declines the contract, her expected welfare stays at the reservation level in (15), which we denote as

$$v_0 = \int_{PC} (\phi\alpha - P_C) dF,$$

while access to the blockchain platform provides a welfare (after the fee) of $v_B - f_B$. Thus, the amount of the fee that makes her indifferent is\(^{33}\)

$$f_B = \Delta v_B \equiv v_B - v_0 = \int_\alpha (\Delta \pi\alpha - \Delta P) dF.$$  

(17)

In other words, the blockchain manager can charge a fee up to the amount of the welfare gain given by (17). We can see this amount as the "price" of the blockchain technology or platform, since traders are willing to "buy" the right to participate in the B-market at the price of $f_B$. Moreover, we have the following intuitive result.

**Proposition 6.** The fundamental price of the blockchain is perfectly correlated with the trading value in the B-market and the price of cryptocurrency $Q$ if the CIA constraint is assumed:

$$f_B = \frac{\pi(1 - \phi)}{2} K_B P_B = \frac{\pi(1 - \phi)}{2} Q.$$  

(18)

**Proof.** See equation (39) in Appendix D1.. \(\square\)

**Corollary 2.** The sophistication of the blockchain technology has the same impact on $f_B$ as proposed by Proposition 5.

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\(^{30}\)The assumption that the manager is a monopolist is also realistic at this point, provided that we have a limited number of blockchain firms for each product. For example, as of February 2018, HyperLedger is the single leading firm that provides a platform for security trading by using the blockchain.

\(^{31}\)We discuss on the fee imposed on the sell side in Appendix F1..

\(^{32}\)Another way to think about the price of the blockchain is to conceptualize $f_B$ as contingent on the usage of the B-market. In this case, the profit of buying in the B-market is shifted down by $f_B$ only if a trader decides to participate. This formulation, however, generates complicated equilibrium conditions because it changes the cutoff of each trader. To avoid complications, we focus on a setting with the ex-ante contract.

\(^{33}\)We assume the tie-breaking rule so that an agent accepts the contract with the blockchain manager if she is indifferent.
This proposition suggests that, if the blockchain uses cryptocurrency, the fundamental value of the technology is perfectly reflected by the price of cryptocurrency. In other words, the price of both cryptocurrency and the blockchain entirely depends on how active the transactions in the B-market are, which is measured by the trading value.\footnote{Moreover, the price of the blockchain technology is multiplied by the coefficient $\pi(1 - \phi)/2$. This value is the multiplier of $\Delta\pi$: when the quality difference is large, the gain from trading in the B-market rather than the C-market is high. When asymmetric information is not severe ($\phi$ is high) or the economy-wide share of low-quality assets is large ($\pi$ is small), the price of cryptocurrency magnifies the fundamental value of the blockchain technology or the welfare gain for buyers (and vice versa).}

### 4.5. Intuitions and Mechanism

The intuition behind the non-monotonic reaction of $Q = P_B K_B \propto f_B$ put forward by Proposition 5 and Corollary 2 is given by the behavior of $P_B$ and $K_B$, together with the migration of buyers.

First, when $\theta$ increases, we find that a more secure blockchain technology tends to widen both price and quality spreads, $\Delta P$ and $\Delta \pi$. The former reduces the demand in the B-market, while the latter increases it, i.e., the B-market guarantees a higher quality but becomes exclusive. Second, the formula $Q = P_B K_B \propto f_B$ implies that $Q$ and $f_B$ rise when $P_B$ increases more than $K_B$ declines. Rewriting the derivative of $Q$ by using elasticity makes this clearer. Since $K_B$ can be expressed as a function of $P_B$ (without $\theta$), and $P_B$ is monotonic regarding $\theta$, we have

$$\frac{df_B}{d\theta} \propto \frac{dQ}{d\theta} = (1 - \varepsilon_{PK}) K_B \frac{dP_B}{d\theta}$$

with

$$\varepsilon_{PK} = -\frac{dK_B / dP_B}{K_B / P_B}.$$  

$\varepsilon_{PK}$ is the price elasticity of the B-market transaction volume. Thus, if the price elasticity of demand is high, a decline in $K_B$ dominates the increase in $P_B$, leading to a smaller $Q$ and $f_B$. To understand the determinants of $\varepsilon_{PK}$, recall that the buyers’ venue choice is driven by how easily they can migrate to the C-market to avoid a higher $P_B$.

When $\phi$ is sufficiently large, asymmetric information is not severe because the difference between the two asset types is small. Then, buyers are not eager to have H-type assets and are not attracted to a high $\pi_B$ in the B-market. Thus, a marginal increase in $P_B$ leads to a larger decline in $K_B$, and the transaction activity in the B-market, measured by the transaction value, $K_B P_B$, diminishes. Hence, the price of the blockchain platform and cryptocurrency drops. If $\phi$ is small, it becomes difficult for consumers to migrate away to the C-market, leading to an increase in $P_B K_B$, $Q$, and $f_B$.

If $\phi$ is intermediate, the level of $\theta$ matters because it determines the difference between the two markets, $\Delta \pi$. If $\theta$ is small, so is $\Delta \pi$: the difference in buying in the B-market and C-markets is not significant in terms of the probability of purchasing low-quality assets. This facilitates migration to the C-market, since this market provides a lower price, while the difference in quality is negligible. This leads to a decline in $K_B$ more than an increase in $P_B$, lowering $Q$ and $f_B$. If $\theta$ is large, the B-market provides a significantly higher average quality, i.e., the quality spread is large, and $Q$ and $f_B$ increase with $\theta$.

The bottom line is that, depending on the underlying information asymmetry, the change in the market structure has a different impact on the market activity. Specifically, even if the blockchain technology could reduce asymmetric information, it does not always make this market attractive for consumers and may even dampen its trading value.
4.6. Optimal $\theta$ and Welfare Distortion

Now, we seek to determine the optimal level of $\theta$ from the perspective of traders’ welfare and the blockchain manager. Suppose that the manager tries to maximize her fee revenue from the buy side of the market, $f_B$. The analogous discussion on fee maximization when it is imposed on sellers is provided in Appendix F1.

In this subsection, we compare the maximization of the fee by the manager to the maximization of buyers’ aggregate welfare, which may be performed by a social planner, e.g., FinTech regulation (or promotion) by the government. Note that the choice of the objective function is highly arbitrary. However, the evidence from the wine blockchain by the EY Advisory suggests that the platform imposes a fee on the buy side of the market.

First, $\theta$ has the following impact on the aggregate consumers’ welfare $v_B$:

**Proposition 7.** (i) $\frac{dv_B}{d\theta} > 0$. (ii-1) When $\pi > 1/2$, $\frac{dv_B}{d\theta} > 0$.

(ii-2) When $\pi \leq 1/2$, there is a unique $\phi_2$. If $\phi < \phi_2$, then $\frac{dv_B}{d\theta} > 0$. Otherwise, there is a unique $\theta^{**} \in (0, 1]$ such that $\frac{dv_B}{d\theta} \geq 0 \iff \theta \geq \theta^{**}$.

**Proof.** See Appendix D1..

Together with $Q$ and $f_B$, buyers’ welfare also has a $U$-shaped trajectory for a certain set of parameters. The reservation welfare is monotonically increasing in $\theta$ because a higher $\theta$ lowers $P_C$ more than it decreases $\pi_C$ due to the same mechanism as in Proposition 4-(iii).

The remaining part of $v_B$, which perfectly correlates with $P_B K_B$, generates non-monotonicity in $v_B$ by the same mechanism as mentioned in Subsection 4.5.

Moreover, the result depends on $\pi$. When $\pi$ is relatively high, the marginal increase in the fraction of assets rejected by the blockchain, $(1-\pi)\theta$, is small. That is, innovation does not cause a large quality improvement or a huge reduction of $K_B^{\phi}$ since the economy does not have a significant amount of low-quality assets to begin with. The increment in $P_B$ caused by the higher $\theta$ is not significant enough to confound the demand in the $B$-market, and the welfare gain represented by the first term in (15) stays high.

4.6.1. Optimal $\theta$ for the Platform Manager

By looking at (15) and (17), we notice that the objective functions of the blockchain manager and the social planner are different, as the manager does not care about the reservation welfare, $v_0$. From (16), we also know that a higher $\theta$ monotonically increases $v_0$ by lowering the price in the $C$-market. Thus, the manager undervalues the marginal benefit of increasing $\theta$ compared to buyers’ total welfare.

Formally, let $\theta^*_M = \arg \max_{\theta \in [0, 1]} f_B(\theta)$ and $\theta^*_V = \arg \max_{\theta \in [0, 1]} v_B(\theta)$, which represent the levels of $\theta$ that maximize the fee and buyers welfare, respectively. Even though it is difficult to analytically determine $v_B(\theta = 1) \geq v_B(\theta = \theta_0)$, it is obvious that $\theta^*_M \neq \theta^*_V$ when $f_B$ is monotonically decreasing and $v_B$ is monotonically increasing.

**Proposition 8.** If $\{\pi > \frac{1}{2}$ and $\phi \in [\phi_1, 1]\}$ or $\{\pi \leq \frac{1}{2}$ and $\phi \in [\phi_1, \phi_2]\}$, then $\theta_0 = \theta^*_M < \theta^*_V = 1$. If $\{\phi < \phi_0$ and $\pi > \frac{1}{2}\}$ or $\{\pi \leq \frac{1}{2}$ and $\phi < \phi_2\}$, then $\theta^*_M = \theta^*_V = 1$.

Proposition 8 tells us that, depending on the parameters, welfare loss arises from the conflicting objectives of the manager and the government. The numerical results are shown in Figure 3 when $f_B$ or $v_B$ has a $U$-shaped curve.

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35The previous subsection assumes that only one buyer is offered the contract. Even if the entire set of buyers is offered it, maximizing $f$ is still optimal since the measure of buyers is one and they are ex-ante identical.
This highlights an interesting implication. If the underlying asymmetric information is mild (φ is high), as in the left and middle panels, the marginal increase in θ tends to dampen the activity in the B-market. This results in a lower welfare gain in the B-market and reduces the fee revenue for the manager. Thus, the manager prefers to keep θ low (θ = θ₀). The social planner, however, knows that a higher θ boosts the reservation welfare, and this increment can compensate for losses in the B-market when φ is relatively high. The level of θ that maximizes buyers’ welfare is therefore θ = 1. Thus, the blockchain platform operated by the manager is under-secured in the sense that the reduction of asymmetric information is not enough to achieve the maximum v_B.

On the other hand, when asymmetric information is relatively severe, as in the right panel, a higher θ facilitates activity in the B-market because P_B increases more than K_B declines. In this case, the fee revenue positively responds to a higher θ, and so does v_B. Therefore, the blockchain market operated by the manager can maximize buyers’ welfare.

The literature on strategic management, such as Teece (1986) and Brandenburger and Stuart Jr (1996), suggests that a firm does not fully adopt innovation, although it creates value for consumers. This is because a firm cannot extract full welfare gain of consumers generated by innovation. We show that this issue arises in the blockchain technology as well, since the manager cannot extract the value in the traditional C-market created by the blockchain technology.

4.6.2. Government Intervention

The preceding discussion indicates that the blockchain manager values an increment in θ as highly as the social planner only if the price elasticity of the demand is small, i.e., a higher θ boosts the trading value in the B-market. This coincidence tends to occur when the underlying information problem is severe because it imposes a higher cost on the migration of buyers. If the market is closer to complete in terms of φ or Δπ, the manager prefers a lower θ than the socially optimal level since she dislikes a decline in the transaction value in the B-market that is caused by the small cost of changing trading platforms.

This implies that the government should intervene in the intermediation chain to facilitate transactions through the blockchain and to increase θ when the traded goods suffer from non-severe asymmetric information. In contrast, it should remain neutral when the information problem is severe since the manager voluntarily maximizes consumers’ welfare. This runs counter to the traditional views on government intervention in markets with adverse selection (e.g., OTC markets after the recent financial crisis), which believe the government should meddle when adverse selection is more severe to avoid market breakdowns.

Our conclusion is driven by the fact that asymmetric information arises among agents, while the platform
manager, who has a tool to mitigate the problem, is interested only in the fee revenue from a certain part of the market. The government does not have a tool to detect the lemons and must rely on the technological innovation in our model that may differ from the situation in which it intervened in OTC markets.

5. Empirical Implications

We can derive several empirical inferences regarding the fundamental value of cryptocurrency and the blockchain and their comparative statics. If we take the model with a CIA constraint, we get the following arguments. (i) The asset price in the blockchain platform is higher than that in the cash market (Proposition 2). (ii) As the blockchain system becomes secure, the asset price in the blockchain platform (resp. cash market) increases (resp. decreases) as in Proposition 4. (iii) For the same situation, the trading value in the blockchain platform and the cryptocurrency price increase if the asymmetric information is severe, while it declines otherwise (Proposition 5).

If we have a dataset that contains the transaction price in a market with the blockchain technology, smart contracts, and cryptocurrency, we can test implication (i) by comparing this price to that in the traditional market. In addition, if we have data from the scratch of the transaction system, we can keep track of the price in the blockchain market and the corresponding price in the traditional market to verify implication (ii).

Implication (iii) is striking: improvements in the blockchain security system do not necessarily increase the trading value and demand for cryptocurrency. On the one hand, this implies that enhancement in blockchain security does not have a robust testable implication. On the other hand, with a dataset and a sufficient exogenous change in $\theta$, our model provides a new measure for the degree of asymmetric information and adverse selection by analyzing how $\theta$ affects the transaction value in the $B$-market.

Additionally, considering the welfare results in Subsection 4.4., the value of the blockchain system is proportional to the fundamental price of cryptocurrency (Proposition 6). This has several applications. First, if we have data that measure the value of the blockchain defined in Subsection 4.4.2. (e.g. ex-ante entrance fee in the $B$-market) and the cryptocurrency price therein, we can directly test the implications of (18). Second, even if transactions are not done using cryptocurrency, Proposition 6 tells us how we can predict the welfare-relevant performance of the blockchain platform.

Since, as of the date of this study, the application of the blockchain in state-contingent transactions is still in its initial stages, we will empirically evaluate these implications in future projects. As the first step, a qualitative finding consistent with our theoretical model arises from the introduction of the blockchain in the wine supply chain. A consulting firm, EY Advisory & Consulting Co. Ltd. (EY), pioneered the blockchain-based administration of the quality of each step of the production of wine, such as grape harvesting, fermentation and bottling, wholesaling, and retail. From talks with corresponding consultants, we confirm that the aim of introducing the technology is to enhance the satisfaction of both customers and suppliers, by guaranteeing the products quality.

Information on the wine blockchain was kindly shared by EY Japan. It reveals the financial results of two clients in 2018. One client’s retail price per bottle increased from 7.00 to 9.20 Euros, whereas other’s increased from 7.00 to 7.46 Euros. Under the assumption that the underlying trend of wine prices is constant, this finding is consistent with empirical prediction (i). The report also contains information on the investment and ROI, which were 53,000 Euros and 7.92%, and 113,000 Euros and 13.94%, respectively. These numbers do not include the value of improving business efficacy due to the blockchain, such as digitalization and more efficient management. In sum, investment in the blockchain generates positive return for the client firms.
6. Conclusion

We develop a simple model to analyze some economic implications of the blockchain technology as a new transaction platform. Following the notion of the smart contract, we consider the blockchain protocol as a way to mitigate asymmetric information and investigate the effect of technological sophistication (innovation) on the economy.

Firstly, the blockchain as a platform causes the segmentation of the trading venues and the differentiation of both sides of the markets (buyers and sellers). We consider asymmetric information among the agents and show that the segmentation and differentiation endogenously generate spreads in the price and quality of the assets traded in segmented markets.

We find that the sophistication and innovation of the blockchain have non-monotonic effects on the trading value in the blockchain, the fundamental value of the platform, the price of cryptocurrency, and consumers’ welfare. That is, innovation does not necessarily increase the value of the blockchain and consumers’ welfare. This is because a more sophisticated blockchain attracts high-quality assets and boosts their price. Since the price increases more than the quality, the blockchain platform becomes “an exclusive market.” When the underlying asymmetric information is not severe, innovation makes a large number of consumers migrate away from the blockchain platform to the traditional one, because they are willing to accept lower-quality assets to save a price cost.

The non-monotonicity leads to a welfare loss when a platform manager, who competes with the traditional market, controls the level of innovation. Since a very sophisticated blockchain platform is not attractive for most consumers, the platform cannot charge a high access fee. Thus, the manager has an incentive to keep the innovation level lower than the first best.

A few issues, such as empirical implications, cannot be investigated well without the availability of further data. Nonetheless, this model proposes the first theoretical framework to study the measurable outcomes of new digital innovations. In addition, one possible future project is the extension of this framework into a dynamic setup. Specifically, this model can be modified to analyze a structure of overlapping generations and time-varying stochastic dividends of the assets, as per the previous literature. Together with the blockchain mechanism, the supply function of cryptocurrency is another salient difference of the blockchain from traditional cash, as Schilling and Uhlig (2018) point out, and incorporating both of these factors provides a more comprehensive pricing theory for cryptocurrency.

Even though the blockchain technology and cryptocurrency are still in their nascent and pivot around speculation, their influence is growing and their potential applications are being vigorously sought. Therefore, we believe that the analyses of their fundamental effects in our theoretical model will have important implications not only for financial markets, but also for the entire economy.

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A Appendix: Motivating Examples for \( \theta \)

Smart Contract: Reduction in Asymmetric Information

Consider an agent who wants to purchase a good (say, a box of wines). A value of the wine for the consumer depends on multiple dimensions of state, \( S = (s_1, s_2, \ldots, s_N) \). We can think of them as a brand of grape, a producer, vintage, storage conditions, and so on. There are \( N \)-steps of intermediations between a wine producer and consumer, and each step is operated by an anonymous intermediary whose type is either \( H \) or \( L \) (see Figure 4). The state \( s_j \) denotes the type of the intermediary and takes two values, \( s_j \in \{s^H, s^L\} \), with \( \Pr(s_j = s^H) = p \).

We simplify the arguments by assuming that the consumer’s private value of the good is positive if, and only if, all the states are high, \( S = S^H \equiv (s_1^H, s_2^H, \ldots, s_N^H) \). Otherwise, the good is valueless. Each intermediary is rewarded equally only if the good is sold. 36

To describe asymmetric information about the quality of the good, suppose that a “label” of the wine tells only an announced states \( \hat{s} \) alleged by intermediaries, and the true state is not verifiable: the consumer gets to see only \( \hat{S} = (\hat{s}_1, \cdots, \hat{s}_N) \). Since the consumer’s private value is positive only if \( S = S^H \), announcing \( \hat{s}_j = s^H \) is optimal for all \( j \), which results in \( \hat{S} = S^H \).37 This describes a typical situation in which a consumer is devoid of a comprehensive knowledge to value a good—it is hard to identify the quality of a wine before she purchases and drinks it. This is represented by the first row of intermediations in Figure 4.

Figure 4: Intermediation by Cash and Blockchain

Now, we introduce the blockchain protocol (the second row of intermediations in Figure 4). If the transaction at step \( j \) is consummated through the blockchain, then the announced state \( \hat{s}_j \) is supposed to be credible, i.e., \( \hat{s}_j = s_j \), and the scripts on Ethereum make transactions take place only if all the past states are \( H \).

We define \( \hat{\theta} \) as the fraction of intermediations that adopt blockchain transaction, and \( \theta : [0,1] \rightarrow [0,1] \) as the fraction of low-quality goods rejected in the intermediations chain (as a function of \( \hat{\theta} \)). Define \( \pi(\hat{\theta}) \equiv \Pr(S = S^H | \hat{\theta}) \).39

If there is no transaction conducted by the blockchain, we have \( \pi(0) = p^N \equiv \pi \), and \( 1 - \pi \) fraction of the goods in the retail store (step \( N \)) are of low-quality. We see this as a benchmark, in which only traditional means of transaction is used. Now, suppose that \( 0 < M \leq N \) steps of intermediations are conducted by the blockchain technology; \( \hat{\theta} = \frac{M}{N} \).40 Then, the resulting probability of the high-quality goods in the retail store is

36Rewards do not have to be specified in this example. Any positive rewards, such as private value and monetary payoff, contingent on the purchase of goods by buyers generate the same results.

37If the good contains \( s^L \) for some step-\( j \), the consumer does not buy the product from the intermediary-\( N \) (i.e., a retailer). Then, if \( \hat{s}_j = s^H, \forall j \leq N - 1 \), it is optimal for the retailer to announce \( s^H \) and sell it at her store. On the other hand, if there is some \( j \leq N - 1 \) who announced \( s^L \), then the retailer does not accept the goods knowing that she cannot sell them to the consumer. By taking this argument backward, we can say that the all goods sold by the retailer have the same label with \( \hat{S} = S^H \).

38Adopting these arguments into Bitcoin blockchain is easy; The traded asset is bitcoin itself, state \( s_j \) represents the balance of bitcoin on traders’ accounts at date \( l = j \), and traders may have a transaction or liquidity shock (state) in each period, which determines the state in the current period. For instance, \( s_j \) is either “spent x amount of coin (\( s_j = s_{j-1} - x \))” or “earn additional y amount of coin (\( s_j = s_{j-1} + y \))” with some probability.

39A set of information also includes \( \hat{s} \), but this does not convey any information since all of the intermediaries have an incentive to announce the high state regardless of their true types.

40Since we set \( p_j = p \), we can assume, without loss of generality, that first \( M \) steps are executed through blockchain.
\( \pi(\hat{\theta}) = p^{N-M} \). By the definition of \( \theta \), this can be expressed in terms of \( \theta \):

\[
\pi(\hat{\theta}) = \frac{\pi}{\pi + (1-\theta)(1-\pi)},
\]

which is the probability of the high-quality goods conditional on the goods are sold in the retail store after \( \theta \) fraction of low-quality goods are rejected. By equating these two expressions, we can rewrite \( \theta \) as a monotonically increasing function of \( \hat{\theta} \):

\[
\theta = \frac{1 - p^N\hat{\theta}}{1 - p^N} \in [0, 1].
\]

Thus, in this discussion, as the number of transactions founded on blockchain technology (\( \hat{\theta} \)) increases, the probability of rejecting low-quality goods (\( \theta \)) monotonically increases.

In the main model, we use \( \theta \) as a metric of the blockchain security, i.e., the power of the blockchain technology to reduce the economy wide asymmetric information. In other words, we can think of this example as a micro-foundation of \( \theta \) in the main model by making the step-\( N \) retailer the “sellers.” In Appendix E, we adopt this architecture into some real-world examples: Bitcoin and Ethereum. It also provides examples of blockchain platforms not associated with circulation of cryptocurrency.

**Time-Consuming Transactions**

One of the most salient benefits of state-contingent transactions manifests itself in international trade or remittance. It is well known that it takes a huge cost and time to settle international trade of goods because it involves mostly manual paper works, authorization of banks in both countries, and jurisdiction problems. This also applies to the international remittance in which we need to authenticate bank accounts of both parties.

We can describe this situation by using the example above. Suppose that Alice in California wishes to send money to Bob in Africa, while there is a chance that Bob’s account is not authentic and he may run away without sending back money or goods. The start of the chain (\( j = 0 \)) is Bob who is either a good or bad agent (bank account is authentic or not), and all other intermediaries (\( j = 2 \sim N \), say banks) try to verify that Bob at \( j = 0 \) is authentic.

For banks, verification may take a long time or even impossible (\( s_j = L \)) with probability \( 1 - p \). Alice is in need of immediacy, and \( S \neq S^H \) takes a toll due to a delay cost. If the transaction is conducted by Bitcoin, however, it can be dramatically secure because of the above-mentioned mechanism and no longer takes a long time (it makes \( s_j = S^H \)). We can interpret \( \hat{\theta} \) as a fraction of transactions that introduce the blockchain and reduce the time for verification. Then, it reduces the possibility of delay by \( \theta \), making the trade more efficient.
B Online Appendix: Generalized Model with Uninformed Sellers

Consider the same structure as in the main model. In addition, assume that a seller is informed with probability $\lambda$ and uninformed with probability $1-\lambda$. If one is informed, she knows a specific characteristic of high-quality assets and can distinguish the lemons, while uninformed agents cannot tell the difference.\footnote{In this case, assume, for simplicity, that the realization of $\alpha$ is independent of the realization of being informed or uninformed.} The optimal behavior of informed sellers is same as the main model.

B1. Optimal Behavior of Uninformed Sellers

Behavior of an uninformed seller is determined by comparing the following returns:

\[
W_U^0 = (\pi + \phi(1-\pi))\alpha, \\
W_U^C = P_C, \\
W_U^B = (\pi + (1-\pi)(1-\theta))P_B + (1-\pi)\theta\phi\alpha. \tag{19}
\]

The first one is the return from consuming her own asset, the second one is the return from selling in the $C$-market, and the last one is the return from selling in the $B$-market. In the last case, she obtains $P_B$ if the transaction is completed, while she ends up consuming her asset if her order is rejected. The two coefficients in (19) represent the probability of successful trade and rejection. Let

\[
\tilde{\pi} \equiv \pi + \phi(1-\phi), \quad \pi_0 \equiv \pi + (1-\pi)(1-\theta)
\]

and define a parameter

\[
\xi \equiv \frac{\pi + (1-\pi)(1-\theta)}{\pi + \phi(1-\pi)(1-\theta) \tilde{\pi}}.
\]

The behavior of uninformed sellers is similar to those of informed sellers with low-quality assets since both of them fear the risk of detection. As we can see from (19), however, the return from selling in the $B$-market, $W_U^B$, is lower than that of informed sellers, $W_B$ in (7), because the return is discounted by the probability that her asset is of low-quality. On the other hand, the return from selling in the $C$-market is not affected by this. Namely, with 100% probability, they can sell the asset of unknown quality. As a consequences, once again, it becomes a price-liquidity tradeoff given the expected continuation value of the asset, which makes relatively low(resp. high)-$\alpha$ sellers trade assets in the $C$-market (resp. $B$-market).

Sufficiently low price in the $B$-market

Therefore, if the price in $B$-market is sufficiently low ($\xi P_B \leq P_C$), trading in the $B$-market is not optimal: they try to sell in the $C$-market or stay inactive. Hence, there is a unique threshold

\[
\alpha^U = \frac{P_C}{\xi}\alpha.
\]

This separates sellers who go to the $C$-market and stay inactive. The amount of sell orders from uninformed sellers is

\[
S_B^U = 0, \\
S_C^U = (1-\lambda)F\left(\frac{P_C}{\xi}\alpha\right),
\]

and it directly corresponds to the supply amount: $K_j^U = S_j^U$. 

Sufficiently high price in the B-market

On the other hand, if the price in the B-market is sufficiently high, \( \xi P_B > P_C \), the uninformed sellers use both of the two markets because the higher price in the B-market strictly outweighs the risk of holding lemons for high-\( \alpha \) sellers. That is, there are two thresholds,

\[
a_0^U = \frac{P_C - \pi_0 P_B}{\phi \theta (1 - \pi)}, \quad a_1^U = \frac{\pi_0}{\pi + \phi(1 - \pi)(1 - \theta)} P_B,
\]

which separate uninformed sellers into three groups. As in the case of informed sellers of low-quality assets, uninformed sellers (i) sell in the C-market if \( \alpha \leq a_0^U \), (ii) in the B-market if \( a \in (a_0^U, a_1^U] \), and (iii) stay inactive otherwise. Hence, the amount of sell orders from uninformed traders is

\[
S_B^U = (1 - \lambda)[F(a_1^U) - F(a_0^U)], \\
S_C^U = (1 - \lambda)F(a_0^U),
\]

and the supply after the screening by the blockchain is

\[
K_B^U = (1 - \lambda)\pi_0[F(a_1^U) - F(a_0^U)], \\
K_C^U = (1 - \lambda)F(a_0^U).
\]

B2. Aggregate Supply and Market Quality

The supply functions in the previous subsections determine the aggregate supply, \( K_B^S \) and \( K_C^S \), as well as the market quality, \( \pi_B \) and \( \pi_C \). Let \( \chi \) be an indicator function for \( \xi P_B > P_C \), i.e., \( \chi = \mathbb{I}_{\{\xi P_B > P_C\}} \). The aggregate supply sums up the supply from both types of sellers:

\[
K_C^S = \lambda (1 - \pi)F(a_1) + (1 - \lambda)\left[\chi F(a_1^U) + (1 - \chi)F\left(\frac{P_C}{\pi}\right)\right] \\
K_B^S = \lambda \left\{\pi F(P_B) + (1 - \pi)(1 - \theta) \left[ F\left(\frac{P_B}{\phi}\right) - F(a_1) \right] \right\} + (1 - \lambda)\pi_0\chi[F(a_1^U) - F(a_0^U)].
\]

By using these equations, we can derive the average quality in both markets:

\[
\pi_C = \frac{(1 - \lambda)\pi\left[\chi F(a_1^U) + (1 - \chi)F\left(\frac{P_C}{\pi}\right)\right]}{K_C^S} \\
\pi_B = \frac{\lambda \pi F(P_B) + (1 - \lambda)\pi_0\chi[F(a_1^U) - F(a_0^U)]}{K_B^S}.
\]

The determination of \( Q \) is the same as before.

B3. Numerical Examples for the General Model

Figure 5 plots the effect of \( \theta \) on the economic variables when asymmetric information is not severe (\( \phi = 0.7 \)).\(^{42}\) As we have anticipated, the improvement of the blockchain security brings about the higher price \( P_B \) and quality \( \pi_B \) in the B-market. However, the direct rejection of \( \theta \) fraction of low-quality assets, as well as the higher price, will have a negative effect on the total trading volume in B-market and \( Q \). The intuition is the same as in the main model proposed in subsection 4.5.

As asymmetric information becomes more severe (\( \phi = 0.5 \)), it becomes more costly for buyers to switch to the C-market. Figure 6 provides effects of improvement in the blockchain technology. When \( \theta \) is small, the difference between \( \pi_B \) and \( \pi_C \) is minimal. Thus, accepting a higher price in B-market is perceived as more costly than improvement of the average quality. Therefore, a marginal increase in \( \theta \) wipes out more traders than it attracts, leading to a larger decline in the trading volume in the B-market than the increase in \( P_B \). The resulting \( Q \) is, therefore, downward sloping.

\(^{42}\)Parameter values for the numerical examples are given by \( \lambda = 1 \) and \( \pi = 0.3 \).
In contrast, when $\theta$ is high, the quality spread, $\Delta \pi$, becomes significant. Although a higher $\theta$ induces a higher price $P_B$, this does not trigger a large migration since buyers try to avoid the significant uncertainty in the $C$-market. In this case, the increment in the price dominates the decline in the transaction volume in the $B$-market, making the transaction value, $P_B K_B$, and the cryptocurrency price, $Q$, increasing in $\theta$.

Figure 5: $\phi = 0.7$

Figure 6: $\phi = 0.5$

C Online Appendix: Proof

C1. Proof for Proposition 1 and 2

The following argument proves the claim under the generalized model with $\lambda \in [0, 1]$ whose equilibrium conditions are provided in Appendix B. Making $\lambda = 1$ proves the proposition for the benchmark model.

Our arguments start from two conditions. In the buyers’ problem, our guesses are

$$P_B \bar{\pi}_C > P_C \bar{\pi}_B \quad (24)$$
and $\pi_B > \pi_C$. \hfill (25)

Given these, the buyers’ partial equilibrium implies that

$$\frac{P_B}{\pi_B} - \frac{P_C}{\pi_C} = (1 - K) + (\hat{\pi}_B - \pi_C)K_C - (1 - K) > 0,$$

where $K = K_B + K_C$. Therefore, we have shown that the inequality (24) holds in the equilibrium as long as the guess (25) is correct (note that (25) and $\pi_B > \pi_C$ are equivalent).

As the next step, we obtain $\pi_B$ and $\pi_C$ in the general equilibrium under the guess (25) and (24). By letting $\Delta \pi = \pi - \pi_C$ and $F$ be uniform, we have

$$\Delta \pi = \frac{\pi}{K_B K_C} \left[ L - \lambda (1 - \lambda)(1 - \pi)(1 - \theta) \beta_0^U \Delta P \right] \hfill (26)$$

where $\Delta P = P_B - P_C$ and

$$L = \lambda (1 - \pi) \alpha_i (P_B + \beta_i^U) + (1 - \lambda) \beta_0^U \lambda (1 - \pi) P_B + (1 - \lambda) (1 - \pi_0) \beta_i^U,$$

$$\beta_0^U = \frac{P_C}{\pi} + \chi \left( \frac{\alpha_0^U - P_C}{\pi} \right), \beta_i^U = \chi (\alpha_i^U - \alpha_0^U).$$

Since both $\alpha_i^U - P_C / \pi$ and $\alpha_0^U - \alpha_i^U$ are (positively) proportional to $\xi P_B - P_C$, we have $\beta_0^U > 0$ and $\beta_i^U > 0$. Therefore, $L > 0$. Moreover, from (6), the difference in prices is

$$\Delta P = (\pi_B - \pi_C)(1 - K_B) = (1 - K_B)(1 - \phi) \Delta \pi, \hfill (27)$$

where we obviously have $K_B < 1$. By plugging this into (26), we obtain

$$\Delta \pi = \frac{\pi}{K_B K_C} \left[ L - \lambda (1 - \lambda)(1 - \pi)(1 - \theta) \beta_0^U \frac{1}{\phi \theta} \Delta P \right] \therefore \Delta \pi = \frac{\pi}{K_B K_C} \left[ \frac{L}{1 + \frac{\pi}{K_B K_C} \lambda (1 - \lambda)(1 - \pi)(1 - \theta) \beta_0^U (1 - K_B)(1 - \phi) \Delta \pi} \right] > 0.$$

Thus, the guess (25) holds in the general equilibrium, and (27) implies $P_B > P_C$.

C2. Proof for Proposition 3

Suppose that we have $\alpha_i > 0$. Then the equilibrium solves

$$K_C^S = (1 - \pi) \frac{P_C - (1 - \theta) P_B}{\theta \phi}, K_B^S = \pi P_B + (1 - \pi)(1 - \theta) \left( \frac{P_B - P_C}{\phi \theta} \right), \hfill (28)$$

$$K_B^D = 1 - \frac{P_B - P_C}{(1 - \phi) \pi_B}, K_C^D = \frac{P_B - P_C}{(1 - \phi) \pi_B} - \frac{P_C}{\phi}, \pi_B = \pi P_B / K_B.$$ 

Let $S = (P_B - P_C) / P_B$ be the normalized spread across markets. Then, rearranging the trading volumes gives

$$K_B^S = 1 - \frac{S}{\pi (1 - \phi)} \frac{S}{P_B}, K_B^S = \pi + (1 - \pi)(1 - \theta) \frac{S}{\phi \theta},$$

$$K_C^S = \frac{1 - \pi}{\phi} P_B \left( 1 - \frac{S}{\theta} \right), K_C^D = \frac{SK_B^S}{\pi (1 - \phi)} + \frac{P_B S}{\phi} - \frac{P_B}{\phi}.$$ 

By equating $K_C^S = K_B^S$, and substituting $K_B^S$, we get a quadratic equation for $S$. Namely, in the equilibrium, $S$ solves

$$\frac{S}{1 - \phi} + \frac{(1 - \pi)(1 - \theta)}{\phi \theta (1 - \phi)} S^2 + \frac{S - 1 - \pi}{\phi} + \frac{1 - \pi}{\theta \phi} S = 0.$$
Note that the LHS is monotonically increasing in $S(>0)$, and the condition $\alpha_I > 0$ is identical to $S < \theta$ by definition (8). Thus, in the equilibrium, $\alpha_I > 0$ if and only if
\[
\frac{\theta}{1 - \phi} + \frac{(1 - \pi)(1 - \theta)}{\phi\pi\theta(1 - \phi)}\theta^2 + \frac{\theta - 1}{\phi} - \frac{1 - \pi}{\phi\theta} = 0,
\]
which can be rewritten as
\[
\theta^2(1 - \pi) - \theta + \pi(1 - \phi) < 0.
\]
Note that if $\theta = 0$ then the LHS of this inequality is positive, while if $\theta = 1$ then it is negative. Thus, the smaller solution of the equation $\theta^2(1 - \pi) - \theta + \pi(1 - \phi) = 0$ is between 0 and 1. We set this solution as $\theta_0$.

Next, suppose that $P_C - (1 - \theta)P_B \leq 0$. This induces $\alpha_I = 0$ by definition (8), and the equilibrium solves
\[
K_0^\delta = 0, K_B^\delta = \pi P_B + (1 - \pi)(1 - \theta)\frac{P_B}{\phi},
\]
\[
K_B^D = 1 - \frac{P_B - P_C}{\pi_B - \phi}, K_C^D = \frac{P_B - P_C}{\pi_B - \phi} - \frac{P_C}{\phi},
\]
\[
\pi_B = \frac{\pi P_B}{K_B}.
\]

By using the market clearing in $C$-market and the definition of $\pi_B$, we obtain
\[
K_B^D = 1 - \frac{mP_B - \phi}{(1 - \phi)\pi P_B} K_0^\delta, K_B^\delta = \left(\pi + \frac{(1 - \theta)(1 - \pi)}{\phi}\right) P_B,
\]
with $m = 1 + \pi\phi + (1 - \pi)(1 - \theta)$. By clearing $B$-market, we have
\[
P_B = \frac{\phi(\pi + (1 - \pi)(1 - \theta))}{(2 - \theta(1 - \pi))(\phi\pi + (1 - \pi)(1 - \theta))},
\]
\[
K_B = \frac{\pi + (1 - \pi)(1 - \theta)}{2 - \theta(1 - \pi)}.
\]

Moreover, we can express the market clearing in $B$-market by using $S$:
\[
K_B \left(1 + \frac{S}{\pi(1 - \phi)}\right) = 1.
\]

By plugging the explicit solution of $K_B$, we have
\[
S = \frac{\pi(1 - \phi)}{\pi + (1 - \pi)(1 - \theta)}.
\]

Since $S$ is monotonically increasing in $\theta$, the condition $P_C - (1 - \theta)P_B \leq 0$ is identical to $\theta < S$, that is
\[
\theta^2(1 - \pi) - \theta + \pi(1 - \phi) \geq 0.
\]

Therefore, the condition is $\theta \leq \theta_0$, and we have established that the equilibrium is continuous at $\theta = \theta_0$.

**Corollary 3.** When $\theta \leq \theta_0$, $P_B$, $\pi_B$, $Q$, and $v_B$ are monotonically increasing in $\theta$.

**Proof.** Results for $P_B$ and $\pi_B$ are obvious from (30) and (29) in Appendix C2. By using (30) and (31), we have
\[
Q = \left(\frac{\pi + s}{1 + \pi + s}\right)^2 \frac{\phi}{\phi\pi + s}, s = (1 - \pi)(1 - \theta).
\]
Then
\[
\frac{dQ}{ds} \propto 2(\phi\pi + s) - (\pi + s)(1 + \pi + s) \equiv D_Q,
\]
and
\[
(1 - \pi)D_Q = -\theta^2(1 - \pi) + \theta - \frac{1 + 2\pi(1 - \phi)}{1 - \pi} < 0
\]
where the last inequality comes from $\theta \leq \theta_0$. With the fact that $ds/d\theta < 0$, we have $dQ/d\theta > 0$. □

**C3. Proof for Proposition 4 and 5**

To see the uniqueness, we plot these $K_B$’s against $P_B$ (see Figure 7). Obviously, $K_B^S$ is positive linear function in $P_B$. We can also check that $K_B^D$ is concave, has only one inflection point in $P_B > 0$, and $\frac{dK^D_B}{dP_B} < 0$ for a sufficiently large $P_B$. Since $K_B^D = 1 > K_B^S$ at $P_B$ such that $K_B^S = 0$, these two curves cross only once in $P_B > 0$.

First, by $K_B^D + K_B^C = 1 - P_C/\phi$, and equating $K_B^D = K_B^S$, we obtain

$$P_C = \frac{\phi}{2 - \pi} (1 - \pi P_B).$$

(32)

Now, suppose that $\theta$ increases. This is represented by the red curves in Figure 7.

![Figure 7: Effect of $\theta$ on B-market](image)

We have

$$p^* = \frac{\phi}{2 - \pi (1 - \phi)}$$

(33)

such that $P_B \succeq P_C \iff P_B \succeq p^*$. Also, let $g \equiv \frac{1 - \phi}{\pi}, \eta \equiv 1 + \frac{\phi \pi}{2 - \pi}$. In the equilibrium, we have $K_B^S = K_B^D \equiv K_B$, so that they are respectively expressed as

$$K_B = P_B \left[ \pi + (\frac{1 - \pi}{\phi})g \eta \right] - \frac{1 - \pi}{2 - \pi} g \eta$$

$$K_B = \frac{(1 - \phi)\pi P_B}{((1 - \phi)\pi + \eta)P_B - \frac{\phi}{2 - \pi}}.$$  

(34)

By equating these two equations and rearranging it in terms of $y \equiv P_B^{-1}$, we obtain

$$H(y, g) \equiv \left( \pi + \frac{1 - \pi}{\phi} \right) g \eta - \frac{\pi (1 - \phi) y}{((1 - \phi)\pi + \eta) - \frac{\phi}{2 - \pi} y} - \frac{1 - \pi}{2 - \pi} g \eta = 0.$$  

For this function, we have

$$\frac{\partial H}{\partial \gamma} = \frac{1 - \pi}{\phi (2 - \pi)} (2 - \pi (1 - \phi) - \phi y) > 0,$$

(35)

$$\frac{\partial H}{\partial y} = -\frac{\pi (1 - \phi)((1 - \phi)\pi + \eta)}{[((1 - \phi)\pi + \eta) - \frac{\phi}{2 - \pi} y]^{2}} - \frac{1 - \pi}{2 - \pi} g \eta < 0.$$  

(36)

Note that both inequality comes from $P_B > P_C$ (equivalently, $P_B > p^*$). These confirm, by the implicit function theorem, $dP_B/d\theta > 0$.  

6
We rearrange the equation for $\pi_B$ as
\[
\pi_B = \frac{\pi}{\pi + \frac{1}{\phi}\frac{\partial}{\partial \theta}} (1 - \frac{P_C}{P_B})^2,
\]
which implies
\[
\text{sgn} \left( \frac{d\pi_B}{d\theta} \right) = -\text{sgn} \left( \frac{d\pi_B}{d\theta} \right) = \text{sgn} \left( \frac{d}{d\theta} \left[ g(1 - \frac{P_C}{P_B}) \right] \right).
\]
By using (32), we can rewrite the inside of the last brackets:
\[
1 - \frac{P_C}{P_B} = 1 - \frac{\frac{\partial}{\partial \theta}(1 - \pi P_B)}{P_B} \propto \frac{2 - \pi(1 - \phi) - \phi y}{2 - \pi}.
\]
Hence, the last term can be calculated as follows.
\[
\frac{d}{d\theta} \left[ g(2 - \pi(1 - \phi) - \phi y) \right] = 2 - \pi(1 - \phi) - \phi y - g\phi \frac{\partial H/\partial y}{\partial H/\partial y} = \frac{2 - \pi(1 - \phi) - \phi y}{\pi(1 - \phi)((1 - \phi)\pi + \eta)} > 0
\]
where the second line comes from the implicit function theorem, and the third to last lines are due to (35), (36) and $P_B > p^*$. Thus, we established that $\frac{d\pi_B}{d\theta} > 0$. Also, $K_B$ is decreasing in $\theta$, which is immediate from (34).
The statement (iii) can be checked by the decreasing $K_B$ and $\Delta P/\Delta \pi = 1 - K_B$ in the equilibrium.
As for the price $Q$, (34) yields
\[
QB_S = P_B K_B = \frac{(1 - \phi)\pi P_B^2}{((1 - \phi)\pi + \eta)P_B - \frac{\phi}{2 - \pi}}.
\]
Since the right hand side does not contain $\theta$, taking a derivative of the last term is
\[
\frac{dQ}{d\theta} = \frac{dP_B}{d\theta} \frac{dQ}{dP_B} \propto (\eta + (1 - \phi)\pi)P_B - \frac{2\phi}{2 - \pi}.
\]
Therefore, there is an inflection point
\[
p^{**} = \frac{2\phi}{(\eta + (1 - \phi)\pi)(2 - \pi)},
\]
which determines the sign of the effect:
\[
\frac{dQ}{d\theta} \equiv 0 \Leftrightarrow P_B \equiv p^{**}.
\]
Now, by using the implicit formula $H(P_B^{-1}, g) = 0$ and the fact that $P_B H(P_B^{-1}, g)$ is monotonically increasing in $P_B$, the condition (37) is identical to
\[
A(\theta) \equiv g(1 - \pi)(2\eta - h) + 2\pi[\phi - (1 - \phi)(2 - \pi)] \equiv 0.
\]
Note that $A$ is monotonically decreasing in $\theta$ (this can be confirmed by using $P_B > p^*$ again). By letting $\theta$ fluctuate from $\theta_0$ to 1, we have the following result.
(i) If $\phi > (2 - \pi)/(3 - \pi)$, then $A(\theta) > 0$ for all $\theta \in [\theta_0, 1]$, which implies that $P_B > p^{**}$ always holds in the equilibrium, leading to a monotonically decreasing $Q$. (ii) If $\phi \leq (2 - \pi)/(3 - \pi)$, then $A(1) < 0$, so $Q$ is decreasing in high-$\theta$ region. To understand more global behavior, we need to check if $A(\theta_0) \equiv 0$. By seeing $A$ as a function of $g$, we can define $g^*$ that makes $A(g) = 0$ as
\[
g^*(\phi) = \frac{2\pi(2 - \pi(3 - \pi))}{(1 - \pi)(1 - (1 - \phi)(2 - \pi))}.\]
Since $A(g)$ is increasing in $\phi$, we have $d g^*/d \phi < 0$. Note that we are focusing on $\theta > \theta_0$, which means

$$g < g_0(\phi) \equiv \frac{1 - \theta_0(\phi)}{\theta_0(\phi)}.$$

From the definition of $\theta_0$, we know $\theta_0$ is decreasing and $g_0$ is increasing in $\phi$. We also have $\lim_{\phi \to 0} g_0(\phi) > 0$ and $\lim_{\phi \to 0} g_0(\phi) = I_{\{\pi > 1/2\}} \pi^{-1}$ because $\theta_0 \to I_{\{\pi \geq 1/2\}} + I_{\{\pi < 1/2\}} \frac{\pi}{1 - \pi}$. Figure 8 shows the effect of a smaller $\phi$ on $g^*$ and $g_0$. We have following two possibilities.

**Figure 8: Behavior of $A$**

![Figure 8: Behavior of A](image)

**(ii-a)** Suppose that $\pi \geq 1/2$. Then there is $\phi_0$ that solves

$$g^*(\phi) = g_0(\phi). \quad (38)$$

$\phi_0$ is uniquely determined from the discussion above. In this case, if $\phi < \phi_0$, then $A(g) < 0$ for all $g < g_0$. That is $Q$ is monotonically increasing in $\theta$. If $\phi_0 < \phi < \phi_1$, then we have $A(g) \equiv 0 \iff g \geq g^*$. Thus, we can define $\theta^* = 1/(1 + g^*) \in (\theta_0, 1]$, and $Q$ is increasing when $\theta > \theta^*$ and decreasing when $\theta < \theta^*$.

**(ii-b)** Also, consider the case with $\pi < 1/2$. In this case, we have a unique $\pi^* \in (0, 1/2)$ that solves

$$g^*(0) = \frac{2\pi(2 - \pi)}{(1 - \pi)^2} = \frac{1}{\pi} = g_0(0),$$

or equivalently

$$2\pi^3 - 3\pi^2 - 2\pi + 1 = 0.$$

If $\pi^* < \pi < 1/2$, then $g^*(0) > g_0(0)$. This implies that we always have $\theta^*$ defined by $\theta^* = 1/(1 + g^*) \in (\theta_0, 1]$, and $Q$ is increasing when $\theta > \theta^*$ and decreasing when $\theta < \theta^*$. On the other hand, if $0 \leq \pi \leq \pi^*$, then the arguments go back to the case **(ii-a)** and the same results hold.

### D Welfare Analyses

**D1. Welfare Analyses for Buyers under $\lambda = 1$**

The buyers’ welfare in aggregate is

$$v_B = \int_{\alpha^*}^{\Delta} (\Delta \alpha - \Delta P) \phi F + \int_{P_C/\phi}^{(1 - \alpha^*)} (\phi \alpha - P_C) \phi F$$

$$= \frac{\Delta \alpha}{2} (1 - \alpha^*)^2 + \frac{\phi}{2} (1 - \frac{P_C}{\phi})^2$$

$$= \frac{1}{2} \left[ \pi (1 - \phi) P_B K_B + \frac{\phi}{(2 - \pi)^2} (1 - \pi + \pi P_B)^2 \right], \quad (39)$$
where the second term comes from $\alpha^* = \Delta P / \Delta \tilde{\pi}$, and the last term comes from (32), (13), $K_1^S = K_1^D$, and the definition of $\pi_B$:
\[
\Delta \tilde{\pi} = (1 - \phi) \frac{\pi P_B}{K_B}.
\]
The property of the first term is given by Proposition 5, while the second term is monotonically increasing in $\theta$. Furthermore, by using (34),
\[
2v_B = ((1 - \phi)\pi)^2 \frac{P_B^2}{P_B[\eta + \pi(1 - \phi)] - \frac{\phi}{2 - \pi} + \frac{\phi}{(2 - \pi)^2}(1 - \pi + \pi P_B)^2}.
\]
Note that $\theta$ does not directly affect $v_B$ in this expression. By letting $h \equiv \eta + \pi(1 - \phi)$, we have
\[
\frac{2v_B}{dP_B} \equiv D_B = ((1 - \phi)\pi)^2 \frac{P_B(hP_B - 2\phi)}{(hP_B - \frac{\phi}{2 - \pi})^2} + \frac{2\phi\pi}{(2 - \pi)^2}(1 - \pi + \pi P_B).
\]
The second order derivative yields
\[
\frac{dD_B}{dP_B} = 2((1 - \phi)\pi)^2 \left[ \frac{\left( hP_B - \frac{\phi}{2 - \pi} \right)^2 - hP_B \left( hP_B - \frac{2\phi}{2 - \pi} \right)}{(hP_B - \frac{\phi}{2 - \pi})^3} \right] + \frac{2\phi\pi^2}{(2 - \pi)^2}
\]
\[
= \frac{2((1 - \phi)\pi)^2 \phi^2}{(hP_B - \frac{\phi}{2 - \pi})^3(2 - \pi)^2} + \frac{2\phi\pi^2}{(2 - \pi)^2} > 0.
\]
We also have $P_B(\theta = 1) \equiv \hat{P}_1 = \frac{1 - \phi + \frac{\phi}{n}}{n}$ and can check $D_B(P_B = \hat{P}_1) > 0$. Thus, if $\lim_{\theta \to 0} D_B < 0$, there is a unique $\theta^*$ such that $D_B \equiv 0 \Leftrightarrow \theta \equiv \theta^*$, while if $\lim_{\theta \to 0} D_B > 0$, then $D_B > 0$ for all $\theta$.

The following formulas at $\theta = \theta_0$ simplify the analyses. First, as $\theta \searrow \theta_0$, we have
\[
P_C = \frac{\phi}{2 - \pi} (1 - \pi P_B) = (1 - \theta_0)P_B, \quad (40)
\]
\[
\therefore P_B = \hat{P} \equiv \frac{\phi}{\pi\phi + (1 - \theta_0)(2 - \pi)}. \quad (41)
\]
Moreover, at $\theta \to \theta_0$, we have $\alpha_1 \to 0$ by definition. Since the markets have to clear, at the limit,
\[
\lim_{} K_B^D = \lim_{} \theta \searrow \theta_0 \left( 1 - \frac{P_B - P_C}{\pi B(1 - \phi)} \right) = \lim_{} \theta \searrow \theta_0 \left( 1 - \frac{P_C - P_B}{\pi B(1 - \phi)} \right)
\]
\[
= \lim_{} \theta \searrow \theta_0 \left( 1 - (1 - \pi)\alpha_1 - \frac{P_C}{\phi} \right)
\]
\[
= 1 - \frac{1 - \theta_0}{\phi} \hat{P} = 1 - \frac{1 - \pi + \pi \hat{P}}{2 - \pi} \quad (42)
\]
The first line is the definition, the second line is from the definition of $K_1^D$, the third line is from the market clearing condition in $C$-market, and the fourth and fifth lines are from the definition of $\theta_0$ that gives $\alpha_1 = 0$ and (40). The last line is the other expression from (40). Also, from (34)
\[
\lim_{} K_B = \frac{(1 - \phi)\pi \hat{P}}{((1 - \phi)\pi + \eta)\hat{P} - \frac{\phi}{2 - \pi}}. \quad (43)
\]
Since markets have to clear, all of these expressions (42, 43) have to be identical. That is
\[
\frac{(1 - \phi)\pi \hat{P}}{hP_B - \frac{\phi}{2 - \pi}} = 1 - \frac{1 - \theta_0}{\phi} \hat{P} = \frac{1 - \pi + \pi \hat{P}}{2 - \pi}, \quad (44)
\]
at (41).
Let \( D_{B,0} \equiv \lim_{\theta \to 0} D_B \). By using the equality of the first and last term in (44),

\[
D_{B,0} \propto (1 - \phi)\pi \left( 1 - \frac{\phi}{h\bar{p} - \frac{\phi}{2 - \pi}} \right) + \frac{2\phi\pi}{2 - \pi}.
\]

By using (44) once again, \( h\bar{p} - \frac{\phi}{2 - \pi} = \frac{(1 - \phi)\pi\bar{p}}{1 - \frac{\phi}{2 - \pi}} \). Thus,

\[
D_{B,0} \propto (1 - \phi)\pi \left( 1 - \frac{\phi}{2 - \pi} \frac{1 - \theta_0}{(1 - \phi)\pi\bar{p}} \right) + \frac{2\phi\pi}{2 - \pi} \\
\propto \left[ (1 - \theta_0) + (2 - \pi)(1 - \phi) \right] + 2\pi\phi - \frac{\phi}{\bar{p}} \\
= 1 + (1 - \pi)(\theta_0 - 2\phi).
\]

Note that \( \theta_0 \) is a decreasing function of \( \phi \) and \( \lim_{\phi \to 1} \theta_0 = 0 \). Then, \( \min_{\phi} D_{B,0} = \lim_{\phi \to 1} D_{B,0} = 2\pi - 1 \). Therefore, if \( \pi < \frac{1}{2} \), we can define a unique \( \phi = \phi_2 \) that solves

\[
1 + (1 - \pi)(\theta_0 - 2\phi) = 0.
\]

If \( \phi \leq \phi_2 \) or \( \pi > 1/2 \), then \( D_B > 0 \) for all \( \theta \in (\theta_0, 1) \), and \( v_B \) is monotonically increasing. On the other hand, if \( \pi \leq 1/2 \) and \( \phi > \phi_2 \), then there is a unique \( \theta^{**} \) such that \( D_B \geq 0 \Longleftrightarrow \theta \in \theta^{**} \).

**D2. Welfare of Sellers**

The welfare of sellers hinges on the quality of assets they are allocated upon their arrival at the economy. The aggregate welfare of \( H \)- and \( L \)-type sellers are defined as

\[
v_{S,H} = \int_{P_B} \alpha dF + \int_{P_B} P_B dF, \\
v_{S,L} = \int_{P_B} \phi dF + \int_{P_B} ((1 - \theta)P_B + \theta\alpha) dF + \int P_C dF.
\]

In both expressions, the first term is the welfare of inactive sellers, while the second term is the welfare of sellers in \( B \)-market. The last term of \( v_{S,L} \) comes from sellers of \( L \)-asset in \( C \)-market. It is easy to check the following proposition:

**Proposition 9.** The welfare of sellers with high-quality assets, \( v_{S,H} \), is monotonically increasing in \( \theta \).

The innovation in blockchain always benefits sellers of high-quality assets because they can always sell their asset in \( B \)-market at the higher price \( P_B \). On the other hand, the global effect of \( \theta \) on \( v_{S,L} \) is hard to determine, though we can obtain the following local result:

**Proposition 10.** \( \frac{dv_{S,L}}{d\theta} \bigg|_{\theta=1} < 0 \), that is, \( \theta = 1 \) cannot be the maximizer of \( v_{S,L} \).

*Proof.* See Appendix D3.. \( \Box \)

Together with Proposition 9, this implies that ex-post welfare of \( L \)-type sellers cannot agree with the welfare of \( H \)-type sellers regarding the optimal \( \theta \).

To obtain more intuitions, we can separate \( v_{S,L} \) into the welfare gain parts and the reservation welfare, as in the case of buyers’ welfare,

\[
v_{S,L} = P_C + \int_{\alpha^l} ((1 - \theta)P_B - P_C + \theta\alpha) dF + \int_{P_C} (1 - \theta)(\phi\alpha - P_B) dF.
\]  \hspace{1cm} (45)

First, all the \( L \)-type sellers certainly can obtain the reservation welfare of \( P_C \) by selling the asset in \( C \)-market (the first term in (45)). If \( \alpha > \alpha_l \), the sellers change the behavior to either selling in \( B \)-market or keeping it. The second term in (45) represents the welfare gain of sellers who will opt-out from \( C \)-market: all of them
(α > α_j) can potentially obtain the additional welfare by selling in B-market. Within this subgroup, agents with relatively high α (such that α > \frac{P_B}{P}) prefer to keep the asset by giving up the revenue \( P_B \), which yields the further welfare gain exhibited by the last term of \( v_{S,L} \).

The first and last terms are monotonically decreasing in \( \theta \). That is, the reservation welfare (the first term) and the gain from changing behavior from selling in \( C \)-market to being inactive decline as the blockchain market becomes more profitable. The sign of the impact on the middle term is affected by two competing effects. On one hand, a higher \( \theta \) boosts the revenue by heightening \( P_B \). On the other hand, it reduces the expected revenue by making the rejection risk higher. The total effect depends on how large the positive welfare gain by the traders in \( B \)-market will be, and it is more likely to happen when the migration of buyers from \( B \)-market is not so large due to the severe information asymmetry and large quality spread. In Appendix D3, we provide further analyses regarding the welfare gain of sellers to complement Proposition 10 and show that the effect of \( \theta \) on \( v_{S,L} \) depends on the elasticity of \( P_B \) with respect to \( \theta \).

D3. Welfare Gain for Sellers

Hypothetically, consider a randomly picked seller who is deprived of the access to \( B \)-market. Ex-ante (before she is endowed with the asset), she expects to have \( v^0_S = \pi v^0_{S,H} + (1 - \pi)v^0_{S,L} \), where \( v^0_{S,i} \) represents the reservation welfare of the seller when she obtains the asset-\( i \) with \( i \in \{L,H\} \). Specifically,

\[
v^0_{S,i} = \begin{cases} 
\int_0^{P_C} P_C dF + \int_{P_C}^1 \frac{\phi}{\pi} dF & \text{for } i = H \\
\int_0^{P_C} P_C dF + \int_{P_C}^1 \phi dF & \text{for } i = L.
\end{cases}
\]

Note that \( P_C \) is the equilibrium price in the segmented market economy rather than the single market economy since we consider a non atomic agent who does not have any impact on the segmented market equilibrium.

For this agent, the expected welfare gain from having access to \( B \)-market is given by

\[
\Delta v_S = v_S - v^0_S = \pi \Delta v_{S,H} + (1 - \pi) \Delta v_{S,L}. 
\]  \( \text{(46)} \)

By applying uniform assumption, we obtain simple formulae:

\[
\Delta v_{S,j} = \begin{cases} 
\frac{1}{2}(P_B^2 - P^2) & \text{if } j = H \\
(1 - \theta) \Delta v_{S,L} & \text{if } j = L.
\end{cases}
\]  \( \text{(47)} \)

Obviously, \( \Delta v_{S,H} \) is monotonically increasing in \( \theta \) since \( P_C \) is monotonically decreasing in \( \theta \). Intuitively, the reservation welfare for sellers with \( H \)-asset is decreasing in \( \theta \) since the terms of trade in \( C \)-market will deteriorate if the blockchain technology improves. That is, the more secure the blockchain becomes, the larger the gain from having the access to \( B \)-market will be for \( H \)-type sellers.

On the other hand, as for \( \Delta v_{S,L} \), we have

\[
\frac{d}{d\theta} \Delta v_{S,L} = \frac{\Delta P}{2\phi} \left[ \frac{\Delta P}{\phi} \frac{d g}{d \theta} + 2 \phi \frac{d \Delta P}{d \theta} \right]
\]

where \( g = (1 - \theta)/\theta \). Since, \( P_C = \phi(1 - \pi P_B)/(2 - \pi) \) in the equilibrium, it becomes

\[
\frac{d}{d\theta} \Delta v_{S,L} = \frac{\Delta P}{2\phi} \frac{d g}{d \theta} \left[ \frac{1}{2 - \pi} \left( 2 - \pi(1 - \phi) \right) \left( P_B(1 - \epsilon_P) - \phi \right) \right] + \epsilon_P = -\frac{d P_B}{d g} \frac{d g}{P_B} > 0.
\]  \( \text{(48)} \)

\( \epsilon_P \) represents the elasticity of \( P_B \) regarding the change in the security \( \theta \) (since \( g \) and \( \theta \) have negative monotone relationship, we consider it as the effect of \( \theta \)). When the elasticity is high, i.e., \( \epsilon_P \) is large, \( \Delta v_{S,L} \) is increasing in \( \theta \). Otherwise, it is decreasing in \( \theta \). Since the welfare gain of sellers with \( L \)-asset comes only from the transaction through \( B \)-market, a higher \( \theta \) has two competing effects. First, a higher \( \theta \) increases the offer price \( P_B \) in \( B \)-market, which has a positive impact on the sellers’ welfare through a higher return from selling. This higher \( P_B \) proliferates the positive impact on \( \Delta v_{S,L} \) by inducing a higher probability of submitting selling order into \( B \)-market. On the other hand, higher security level makes the rejection probability higher. This effect reduces the gain for sellers with \( L \)-asset. Given that the latter effect is a direct consequence of \( \theta \), the first positive effect dominates the latter effect when the increment of \( P_B \) is large, namely, \( \epsilon_P \) is high.
When is the elasticity more likely to be high? It can be translated into the market equilibrium: a higher $P_B$ confounds the demand when the cost of migration for the buyers is low. On the other hand, if the cost of migration is high, the higher price can sustain itself, making the elasticity of $P_B$ high. Thus, $\Delta v_{S,L}$ exhibits upward sloping curve when (i) $\phi$ is low or (ii) $\Delta \pi$ is large.

E Technology Overview

E1. Bitcoin

The leading example of cryptocurrency is Bitcoin. The idea of Bitcoin is first introduced by Nakamoto (2008), who proposes the blockchain technology for the first time. The part of the objectives of this proposal is to offer a solution to the “double spending” problem. Bitcoin is the first success after a long history of proposals of decentralized media of transactions, making it the largest market capitalization in the cryptocurrency trading market (Narayanan et al., 2016).43

The Bitcoin blockchain has recorded the information of the flow of bitcoins across participants (“Alice paid X bitcoin to Bob”) in a tamper-proof manner. In this platform, the traded good is bitcoin itself. To have a concrete idea, we align the transaction of bitcoin with the example in Appendix A.

Suppose that, at date $t = 0$, liquidity providers have liquid assets (cash or bitcoin), and liquidity takers are endowed with illiquid assets whose common value is $k$. At date $t = 1$, takers are hit by a liquidity shock and want to offload (liquidate) their asset holding to obtain (net) utility $v_s - k$ from $s$ amount of liquid cash (or coin), where $v$ is some positive private value. The state of liquidity providers at date $t = 1$ is either $s_t \in \{m, 0\}$, where $s_t$ represents the amount of cash or bitcoin she holds.

To bridge the argument to the example introduced in Appendix A, we can think of the realization of $s_t$ as the result of cumulative transactions: there are dates $t \in \{-N, -(N - 1), \cdots, 1, 0\}$, and each has a state $s_t$ that represents cash flow at each date.

Suppose that $s_t = 0$ realizes (she already spent her cash or coin in the past) for $1 - \pi$ fraction of liquidity providers, and rest of them have $s_t = m$.44 Since announcing $s_t = m$ is strictly dominant for all of the buyers, $1 - \pi$ fraction of them are fraudulent who attempt to use the coin or money they already spent (double-spend). In the traditional cash market without a bank that monitors the accounts of her customers and transactions, fraudulent agents easily spend their money twice (or more) as long as $\pi m > k$, because this inequality means that sellers want to sell the asset.

On the other hand, in the Bitcoin’s network, it is extremely difficult to spend the coin twice because even if the agent with $s_t = 0$ realizes $s_t = m$, this cannot be an agreement. That is, $\theta$ fraction of $1 - \pi$ agents fail to accomplish their fraud transactions, which makes the fraction of honest sellers $\pi(\theta) = \frac{\pi}{\pi + (1 - \theta)(1 - \pi)} > \pi$.

This provides a higher expected return for liquidity takers, and hence they have an incentive to utilize the blockchain platform rather than the traditional transaction.45 In the example of Bitcoin, $\theta$ is very high since the double spending is precluded unless an agent has a prohibitively strong computing power.

E2. Ethereum

As explained in the main text, precluding double spending is not the only feature enabled by the blockchain technology. It also allows us to write complex scripts to determine what kind of information is regarded and added as “relevant” one.46 First, as mentioned earlier, the state information recorded on the blockchain is highly credible. Second, by writing codes such that “transaction takes place if and only if the state $s$ satisfies conditions (1), (2), ..., and (N),” we can make a transaction contingent on desirable conditions (1)-(N).

This technology has many applications to mitigate informational problem in assets transactions, information storage, and allocation.

The wine blockchain, founded by EY Advisory & Consulting Co. Ltd. offers a concrete example.47 Technically speaking, the language for the scripts in Ethereum transactions is Turing-complete, a class of language that allows complex statements. This capacity of allowing complexity makes state-contingent contracts possible.

43As of February 8, 2018
44Assume that $\pi$ is common knowledge, and $m < k < \pi m$ hold so that transactions take place.
45Of course, knowing that $\theta$ fraction of “double spending” fails, the behavior of liquidity providers also changes. We do not go into detail of this point here and leave it for the formal analyses in Section 3 of the main text.
46Technically speaking, the language for the scripts in Ethereum transactions is Turing-complete, a class of language that allows complex statements. This capacity of allowing complexity makes state-contingent contracts possible.
47Other sectors outside the financial service industry, such as supply chain management, are also interested in digitizing and tracking information of products. For example, Walmart Stores Inc. is testing a transaction system on IBM blockchain technology to manage supply-chain data (https://www-01.ibm.com/press/us/en/presskit/59610.wss, visited on May 10, 2018). The products include porks, mangoes, berries and a dozens of other products. It is aimed to identify bad sources throughout the overall chains of food product intermediations.
ditionally, wine market is exposed to a risk of counterfeit (“lemons” in the sense of Akerlof [1970]), whose economic losses is said to be $1-5 billion per year. The problem of low-quality wines is severe since many intermediaries are involved in a supply chain of wine, making it difficult to keep track of all the transactions from ingredient firms to retail stores. By utilizing the blockchain and smart contract, however, transactions of wines become almost free from the lemons’ problem without any credible third-parties or interventions.

In contrast to the example of Bitcoin, which records a flow of coin as a state variable, this example can be directly adopted to the preceding example in Appendix A. That is, state information can take a range of characteristics: it can record a brand of ingredient, name of wine-producer, in what temperature and how long a wine has been stored, and so on. This can also be applied to other classes of assets whose value is difficult to identify for consumers. Given the descriptions of state information, Ethereum allows us to make transactions conditional on realization of desirable states.

### E3. Connection of Blockchain and Cryptocurrency

The two examples the blockchain above use cryptocurrency as a means of transaction. This class of blockchain platforms includes the one for transactions of wines (EY, based on Ethereum), security (tZERO), international remittance (Bitcoin), arts and photography (Kodak, based on KodakOne and KodakCoin), and more.

Another interesting example is Ripple. Although their underlying technology is not exactly the blockchain, Ripple also utilizes a distributed ledger to provide secure transactions between banks and commercial firms, in which cryptocurrency XRP is used. An approval of transaction is not made by Proof of Work (PoW) as in the Bitcoin system, but it is done by a certified set of validating nodes. Hence a transaction is settled faster than in the Bitcoin system, and waste of electricity inherent in the PoW system is relaxed.

There are also blockchain platforms that do not need circulation of cryptocurrencies as a medium of transactions. For instance, EverLedger, providing the blockchain platform for exchanging a variety of assets (wine, art, jewelry), claims that they have no interest in building their own cryptocurrency since they want to avoid many political challenges. Moreover, a number of “permissioned blockchain” platforms do not need to use digital currency or mining process to record information.

For a blockchain platform whose transactions are not necessarily executed by cryptocurrency, the model provides an implication for the fundamental value (price) of the blockchain itself. Specifically, Proposition 6 of the main text proposes a theoretical measure for the price of these types of blockchain technology and show that it corresponds to the welfare gain of participants in the network.

### F Imposing Fee on Sellers

What if the suppliers (or producers of goods) have to pay the fee to use the blockchain? We can fall back on the same logic to derive the maximum possible fee that the manager can charge on sell-side of the market, which we denote as $f_S$:

$$f_S = \Delta v_S$$

with $\Delta v_S$ in (16) of the main model.

When $\Delta v_{S,L}$ is increasing in $\theta$, the total fee $f_S$ is also increasing, while if $\Delta v_{S,L}$ is decreasing, the form of $f_S$ is ambiguous since it depends on the level of $\pi$. Suppose that the parameter values make $\Delta v_{S,L}$ decreasing in $\theta$. Under this situation, it seems natural to conclude that a lower $\pi$ makes $f_S$ downward sloping because it puts more weight on $\Delta v_{S,L}$. However, this is not necessarily the case. For example, if we make $\pi \to 0$, we have $d\Delta v_{S,L}/d\theta \to 0$ and $df_S/d\theta \to 0$. This is because of the dominating $L$-asset in the market. As the level of $\pi$ diminishes, the share of $L$-asset increases, and, at the limit, there are only $L$-asset in both of the markets. This implies that having the access to $B$-market does not payout: the welfare gain converges to zero. Further analyses on the sellers’ willingness to pay are provided in Appendix D as numerical experiments because of the difficulty of an analytical characterization.

### F1. Manager vs. Sellers

Next, suppose that the manager makes money by imposing the fee on the sell-side of the market, while the government tries to maximize sellers’ welfare. From (16), (17), and (18), we know the followings: the welfare

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48For example, see Holmberg (2010) and Przyswa (2014).
49See Buterin (2016) for more details.
50http://www.eweek.com/cloud/hyperledger-blockchain-project-is-not-about-bitcoin
gain of $H$-asset holders is monotonically increasing, imposing a positive pressure on $f_S$, while that of $L$-asset holders has an ambiguous effect. Moreover, Proposition 8 implies that, as long as $f_S$ is monotonically increasing in $\theta$ due to the dominating effect from $d\Delta v_{S,H}/d\theta$, the optimal $\theta$ set by the manager cannot agree with $\theta$ that maximizes $v_{S,L}$. Thus, the welfare of $H$-asset holders is maximized, while sellers with $L$-quality asset incur welfare loss. Proposition 8 implies that there is a conflict between the welfare of $H$-asset holders and $L$-asset holders: once the type of asset is realized, even the social planner cannot maximize the welfare of both types of traders.

Since we cannot analytically characterize the properties of sellers’ welfare further, we rely on the numerical examples. We find the total fee revenue is upward sloping, and the maximizing $f_S$ agrees with maximizing $v_S$, $H$ in most ranges of parameters. Note that the discussion around elasticity makes clear in what situation this welfare loss tends to occur.

**Figures and Tables**

The following figures provide the numerical examples for the sellers’ welfare and fees. Parameters take $\pi \in \{0.01, 0.1, 0.4, 0.7, 0.9\}$, and $\phi \in \{0.35, 0.5, 0.7\}$. The first (second) column shows the total and reservation welfare of $H$-type ($L$-type) sellers, as well as the fee imposed by the manager, $f_S$. The third column is the plot of the total (ex-ante) welfare of sellers and $f_S$.

As suggested by the theory, $v_H$ is monotonically increasing in $\theta$, while $v_{S,L}$ is either monotonically decreasing or hump-shaped. If $f_S$ can be decreasing in $\theta$, that should occur when $\theta$ is relatively high. However, even if we set the share of $L$-type sellers large ($\pi = 0.01$), the configuration of $f_S$ is upward sloping. This is because the change in $\theta$ affects $v_{S,L}$ mostly through the change in $v^0_{S,L}$ when $\pi$ is small. That is, the welfare gain for $L$-type seller, $v_{S,L} - v^0_{S,L}$, is not affected by $\theta$ (see the difference between blue and green-dotted lines). Of course, a higher $\theta$ increases the welfare gain from trading in $B$-market. Meanwhile, it reduces the welfare gain in $C$-market, which has a dominating effect on the welfare because only $1 - \theta$ fraction of selling attempts get to have a benefit of a higher $\theta$.

**Figure 9: Welfare of Sellers and Fee: $\pi = 0.01$**

![Figure 9: Welfare of Sellers and Fee: $\pi = 0.01$](image-url)
Figure 10: Welfare of Sellers and Fee: $\pi = 0.1$

Figure 11: Welfare of Sellers and Fee: $\pi = 0.4$
Figure 12: Welfare of Sellers and Fee: $\pi = 0.7$

Figure 13: Welfare of Sellers and Fee: $\pi = 0.9$