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Formation of Bargaining Networks Via Link Sharing

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Summary

This paper presents a model of collusive bargaining networks. Given a status quo network, game is played in two stages: in the first stage, pairs of sellers form the network by signing two-sided contracts that allow sellers to use connections of other sellers; in the second stage, sellers and buyers bargain for the product. We extend the notion of a pairwise Nash stability with transfers to pairwise Nash stability with contracts and characterize the subgame perfect equilibria. The equilibrium rents are determined for all firms based on their collateral and bargaining power. When a stable equilibrium exists, sharing always generates maximum social welfare and eliminates the frictions created by the network structure. The equilibria depend on the initial network setup, likewise bargaining and contractual procedures. In the homogeneous case, equilibria exist when the number of buyers and sellers are relatively unequal. When the number of buyers exceeds number of sellers, bargaining privileges of sellers over buyers and a low sharing transfer are required for the equilibrium to exist. In the networks with relatively few monopolized sellers, sharing leads to a complete reallocation of surplus to sellers and a zero sharing transfer. When the global market is dominated by sellers, surplus is divided relatively equitably. It is also shown that in the special case of the model with only one monopolistic seller and no market entry, the sharing process organizes sellers in the supply chain order.

Keywords: Social Networks, Oligopoly Pricing, Collusion, Market Sharing Agreements

JEL Classification: L11, L140, L120

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Formation of bargaining networks via link sharing

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Abstract

This paper presents a model of collusive bargaining networks. Given a status quo network, game is played in two stages: in the first stage, pairs of sellers form the network by signing two-sided contracts that allow sellers to use connections of other sellers; in the second stage, sellers and buyers bargain for the product. We extend the notion of a pairwise Nash stability with transfers to pairwise Nash stability with contracts and characterize the subgame perfect equilibria. The equilibrium rents are determined for all firms based on their collateral and bargaining power. When a stable equilibrium exists, sharing always generates maximum social welfare and eliminates the frictions created by the network structure. The equilibria depend on the initial network setup, likewise bargaining and contractual procedures. In the homogeneous case, equilibria exist when the number of buyers and sellers are relatively unequal. When the number of buyers exceeds number of sellers, bargaining privileges of sellers over buyers and a low sharing transfer are required for the equilibrium to exist. In the networks with relatively few monopolized sellers, sharing leads to a complete reallocation of surplus to sellers and a zero sharing transfer. When the global market is dominated by sellers, surplus is divided relatively equitably. It is also shown that in the special case of the model with only one monopolistic seller and no market entry, the sharing process organizes sellers in the supply chain order.

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1 Motivation

The network structure of trading markets has long been recognized in the literature (see Demange and Wooders (2005) and Easley and Kleinberg (2010) for the extensive reviews). It is commonly assumed that network links represent business connections between sellers and buyers, while nodes represent traders. The structure of the network has a strong effect on the equilibrium volume and prices. Networks restrict traders to only local operation and create matching frictions for buyers and sellers. Dense networks provide more opportunities for traders to alternate, and comparing to sparse networks, are characterized by a higher market trade volume.[3]

If the goal of one is to increase system efficiency and number of matched traders, it can be realized by building new connections between traders. Link creation can be processed in different ways with various economical costs. Two main approaches have been used in theoretical modeling of markets on graphs: centralized approach based on matching mechanism and decentralized (game theoretical) approach. When allocation of goods is controlled by the centralized matching mechanism (discussed in Myerson (1977)), adding links between sellers and buyers always increases total market surplus (also see Guzman (2011)). So if link formation induces low cost, the network architecture may increase network connectivity to raise efficiency. In reality, most markets are not controlled by a single network architecture and instead operate according to the law of supply and demand. Thus the network that results from interactions between traders may not be optimal. A network formation process is often the result of actions of market traders, so the link formation may be avoided strategically. The game theoretical literature showed that stability and efficiency are not equivalent for a wide range of network formation games (Jackson and Wolinsky (1996)). It implies that for the decentralized markets, strategic behavior of agents is the key determinant of the equilibrium outcome.

We follow the strategic approach and postulate that networks, as well as prices and quantities, are determined by the trader's individual incentives. The network formation game allows to see explicitly the role of preliminaries, such as network formation rules and initial network structure, for the emerging equilibria, which can potentially provide an explanation for the implicit network formation process observed by the empirical literature.

Employment search is one of the applications of heterogeneous sharing game with indivisible good: current employees freely (sometimes privately or publicly) share information about the open positions with job seekers. The referral process among job seekers helps to reduce search cost and increases the total employment. Likewise employment agencies do job matching professionally and charge a fee for their services. For example, an online job agency may be recruiting a manager at the same time as finding another manager for the client.

With a recent development of online business infrastructure, the question of information sharing has become extremelly important. It is especially the case for the online trading. Internet makes it possible for firms to cooperate freely. However, the costs of consumer search create a network structure based on the popularity of websites, which makes it difficult for new internet projects to become popularized among consumers. When firms exchange information about the demand side, they expand their business and decrease buyer's search costs. Internet giants, as well as small companies, are collecting information about the preferences of consumers and sell it to either competitors or firms in other markets. For example, the Facebook is using an ads manager located on the side of the webpage as a mechanism of access sharing.

[3] The result holds for bilateral bargaining models with complete information, because, ceteris paribus, the size of a maximal matching stays the same or increases when one more link is added to the network.

The mechanism of link sharing may be also applied to such matching problems as allocation of doctors to hospitals or graduates to universities. Though a separate model needs to be developed for the sharing matching, we hypothesize that if low ranked universities were allowed to sell information to the high ranked universities, the market efficiency could be increased.

Finally, the sharing network model provides a theoretical explanation for an industry formation, including formation of intermediaries.[4] It is a fact that the strongest market players often expand by creating a business network (based on franchising or resellers). At the same time, some firms completely specialize on reselling and information sharing. The sharing model goes along with this stylized facts; it also explains why intermediaries do not explode all benefits from connecting sellers.

In this paper, the network formation process results from the cooperative behavior of sellers, which collude in a very specific way: preliminary to the bargaining stage, they share access to buyers with each other. Initially, sellers and buyers are connected via links of a bipartite status quo network G_0. The opportunity to change the network is given to sellers.[5] That is a reasonable assumption for the bargaining markets, because most buyers operate on multiple markets with different products and due to a time constraint and lack of incentives deal only with the firms they know, whereas sellers (firms) invest tons of resources in marketing campaigns and market expansions.[6]

The process of link sharing is similar to selling information about buyer's preferences and locations. In a sense, link sharing model is an expansion of a simple oligopoly model with the multiple small markets operating side by side. In this paper, the model of the sharing network formation is interpreted as a model of legal collusion between firms against consumers. Nowadays, information is widely traded and does not have any restrictions on the seller's location: contact information and market role of most of the sellers can be found using online resources. So any seller may buy an access from any other seller using an internet platform. This allows sharing process to be nonrestrictive and competitive. Due to a nature of information as a non rival benefit of a network sharing process (Bala and Goyal (2000)), it is also assumed that once information is shared, it cannot be forgotten by the sellers. Interesting that a new link formation does not always result in trade between newly matched agents, but always provides an additional bargaining power to both traders. The process of this specific network formation may be applied to very different markets.

The equilibrium concept being used is an extension of a pairwise stable equilibrium with transfers introduced by Bloch and Jackson (2007) . Contracts instead of transfers are considered in the network formation process, and the model is applied to multiple stages. We require actions to be pairwise stable in each subgame, which means that no more than two sellers may deviate as a coalition. Additional to pairwise stability of transfers, transfers are also required to be Nash stable (similar to Gilles and Sarangi (2004)). It allows firms to breach or reconsider old contracts when they involve into a new contract. Given the optimal strategies in each bargaining subgame, the equilibrium strategies in the entire game may be determined using a backward induction. We focus on the link sharing process. Several papers (including Jackson Wolinsky (1996)) have

[4] The model is more relevant to the formation of distributors rather than wholeseller, since the first ones are rarely sell the goods directly and deal mostly with the information services.

[5] Following the classical approach, a link can be formed bilaterally by a pair seller-buyer. On the contrary, this paper does not require buyer's consent for a link formation; the link can be formed only with an accord of another seller who already has an access to the buyer.

[6] Model may be easily changed to the one with buyers forming links.

used transfers to solve the inefficiency problem, but their market mechanisms were not enough to overcome network barriers. It will be shown that together with the link sharing, transfers among sellers can be a mechanism to increase total efficiency.

When the equilibrium of the sharing network formation game exists, network formation always generates market efficiency and maximum social surplus. It means that inefficiency created by the network structure can be eliminated and Walrasian allocation can be achieved. The emerged equilibria depend on the initial network setup, contract terms (transfers and remedies for breach) and bargaining market power of sellers relative to buyers ($z \in [0, 1]$). The homogeneous and heterogeneous networks are considered separately. In the homogeneous case, the equilibrium exists when the number of buyers exceeds sufficiently the number of sellers, or when it is less than the number of sellers; however, when the market sides are relatively equally weighted, no equilibrium exists.

Two different types of equilibria emerge. In the first type of equilibrium, maximum market surplus is completely reallocated to sellers and the price of sharing among sellers is zero. The second type of equilibrium is more favored by buyers, since total surplus is moderately divided between buyers and sellers according to their bargaining power. However, besides the shortage of buyers, another necessary condition should be satisfied to guarantee existence: sellers are required to sign the contracts with the high net sharing transfer[7], and the higher the bargaining power of sellers, the lower the minimum sharing transfer requirement. This requirements also implies that sellers have more bargaining power than buyers.

It is also proved that in the special case with only one monopolistic seller and no market entrants, the sharing process organizes sellers in the supply chain order with some sellers being resellers and others being retailers. Multiple equilibria are possible in this situation. Sellers may share access for free, or for a non-negative transfer which depends on the individual fnet transfer. The latter case is possible when buyers have more bargaining power than sellers. Then retailers that master a high fixed cost level, get access for free, while other retailers pay transfer between zero and buyer bargaining share $1 - z$. Resellers get zero profit with net transfer exceeding their fixed cost level but being less than the buyer bargaining share.

In the heterogeneous case, every sharing equilibrium is also efficient. It means that costs created by market network structure can be completely eliminated by implementing sharing mechanism. However, similar to the homogeneous case, the surplus may be divided unevenly between selling and buying sides.

The paper has the following structure: part II with the literature review follows the introduction part, then part III formally defines the set of feasible networks and rules of the game, solution of the model for different status quo networks G is given in part IV, and finally conclusion summarizes the paper.

2 Literature review

This paper contributes primarily to the literature on network formation games with the application to bargaining markets. The theoretical approach to network formation is based on Bloch

[7] As a result of the network formation process, sellers may become intermediaries and the total transfer for link sharing may be formed collectively by multiple sellers. The deviation of few sellers may result in the insolvency of the intermediary. That is why the pairwise contract is contingent on the behavior of other players. Here, the condition is on the net transfer from e seller to another seller.

and Jackson (2007) . They provide an extension to a standard network formation process adding monetary transfers from one agent to another. In this paper, the model is further extended to the network formation with contracts. It is then applied to multiple stages of the game. The notion of stability in the network formation games was first fundamentally discussed in Jackson and Wolinsky (1996) and then extended by many researchers (see Bloch and Jackson (2006) for the review of equilibrium concepts and Dutta and Bloch (2011) for the recent review of network formation games), we use these concepts to characterize the equilibrium set. The supernetwork approach described in Page and Wooders (2007, 2009) is being used to find the stable sets in the network formation game. This approach is based on eliminating networks with pairwise deviations beneficial to both agents; it guarantees that survived networks (called path dominance core) are pairwise stable for the predetermined game specifications.

The homogeneous case of the sharing networks is basically the extension of the model of Corominas-Bosch (2004) . Particularly, the network decomposition mechanism is used to represent network as a composition of subnetworks of three different types. Corominas-Bosch (2004) characterizes each market with the network decomposition and bargaining power $z \in [0, 1]$, the coefficient that shows what equilibrium is likely to emerge in the standard Nash bargaining game when a continuum of prices are stable. In that work, the coefficient is linked to a time discount factor. In the setup of sharing networks, parameter z has a significant effect on the existence and stability of equilibria. The work of Elliot (2013) combines approaches from Corominas-Bosch (2004) and a paper of Kranton and Minehart (2000) to show that in case of heterogeneous traders the bargaining solution can also be characterized by a single parameter $z \in [0, 1]$. This result indicates that sharing model can be easily extended to a heterogeneous case.

The specifics of each model in the literature on bargaining networks include a bargaining mechanism. Several papers propose different bargaining protocols including Bertrand competition (Lever (2009)), Cournot competition (Goyal and Joshi (2006)), ascending-bid auction (Kranton and Minehart (2000)), alternating-offer bargaining (Corominas-Bosch (2004)), bilateral negotiations similar to Rubinstein-Wolinsky mechanism (198) (Polanski (2007) , Kearns (2007)). In this paper, it is assumed that seller-seller and buyer-seller bargaining happen in the way similar to Bloch and Jackson (2007): both traders propose the amount that will be transferred to another trader for a good or for an access. If the sum of transfers exceeds zero, contract is signed. This protocol does not add additional time frictions like in the models with sequential trading. To form a particular belief system, we select an equilibrium in each subgame that guarantees pairwise stability and in the consistency of beliefs among traders.[8]

Manea (2011) builds an infinite horizon model of a bargaining game. In his paper, matched pairs that reach agreement are replaced by new traders keeping the network structure the same. Similar to this model, given the network, bargaining outcome is dependent on the bargaining power between two agents. Different from this paper, the traders cannot change the network and are restricted to trade with only connected traders.

The idea of contingent contract in the bargaining networks is also captured by Mauleon (2011) . The authors are using linear and two-part tariffs to research stability and efficiency in the networks of manufacturers and retailers; it is shown that the former does not guarantee the later for these types of contracts..

[8]Some papers focus on the bargaining process with a sequence of proposals following some exogenously determined order (see for example Currarini and Morelli (2003)). The sequential approach has its advantages, such as uniqueness of equilibrium, as well as disadvantages, including the strong dependence of equilibria on the exogenously determined mechanism.

The paper is also related to the literature on resellers and changing market structure on a network. There is a paper of Blume et al (2008) that considers a bargaining network with intermediaries. The intuition of this paper is similar to this model; however there are few differences, including that in the sharing network formation sellers can choose between being an intermediary or not being an intermediary. Besides in the sharing game, the intermediary's fee is endogenously determined. Belleflamme and Bloch (2004) also explore oligopoly markets on networks with sharing agreements by which firms commit not to enter each other's territory.

Finally, the process of sharing is similar to the seller referral process, which happens when a match is created between a seller and a buyer by anothe agent. With the development of information markets, referral business model becomes more popular among intermediaries and firms. Likewise, Galeotti (2013) showed that the referral business scheme is preferred by an intermediary to the process of buying and reselling the object. This process helps sellers to avoid search costs, while at the same time it may increase prices due to the collusive nature of the process. Arbatskaya and Konishi (2012) provide the conditions when the referral is beneficial for both sellers and buyers in the non-network setup. We consider the referral process in the markets with a network structure and allow any seller to provide a referral.

3 Model setup

3.1 Structure of the game

In this section, a link sharing game is strictly defined. Bargaining is realized at time t=2, while at time t=1 sellers are allowed to increase connectivity of a network by sharing access to their buyers with other sellers. Sharing increases seller's bargaining power and expands the local markets. The game has the following structure:

- Stage 0: Sellers and buyers are informed about the status quo network G_0 and the parameters of the game.
- Stage 1: Each seller proposes sharing contracts to all other sellers, and in case of consistency signs the agreements. Network G' is formed.
- Stage 2: Given the network G', sellers and buyers bargain for the goods.
- Stage 3: The payoffs are distributed. If sellers are not able to pay the debt, they announce bankruptcy and pay only the guaranteed transfer specified by the contract terms.

Each of the stages is examined in the following paragraphs in details.

3.2 Feasible sharing networks

The market is determined by sets of buyers and sellers and a set of business connections. A buyer and a seller can bargain with each other only if they are connected. Each seller produces one unit of good or nothing, and each buyer demands one unit of the good. For simplicity, the good is assumed to be non-divisible and homogeneous across sellers. Agents gain no utility from holding money. Seller's values (production costs) and buyer's values are exogenously given.[9]

[9]When utility function is linear, assumption that the good is non-divisible is not crucial. When the individual demand function is non-linear, the bargaining problem becomes more interesting. It can be shown that under the

The network representation is useful to operate with the model. A set of nodes and corresponding traders is exogenously given

$$N = S \cup B = (s_1, s_2, s_3, ..., s_n, b_1, b_2, b_3, ..., b_m),$$

where S denotes a set of sellers and B denotes a set of buyers. Before network formation game is started, each seller has access to a non-empty subset of buyers, and each buyer has access to a non-empty subset of sellers.[10] Sellers are connected to buyers via directed arcs.[11] A set of arc types is denoted as $A \subsetneqq N$. We say that an arbitrary seller s_1 and buyer b_1 can trade with each other if and only if there is an arc from node s_1 to node b_1.The initial market structure can be represented by a bipartite graph G_0 with sellers and buyers being nodes and business connections being arcs. Once the sharing stage is complete, new connections are formed. The arcs between sellers are formed in the sharing stage if they share access to one of the buyers. It means that multiple arcs of different types can exist between two sellers if they decide to share multiple buyers. The notation which is robust with respect to this modeling assumptions is the one used by Page and Wooders (2007, 2009), which defines network as a subset of a Cartesian product of a set of arc types A, and ordered pairs $(N \times N)$.

Definition 1. [Sharing network] Given a set of nodes $N = S \cup B$, sharing network G' is defined as a non-empty closed subset of $(A \times (N \times N)$, where each element $(a, (s, b)) \in (A \times (N \times N)$ determines the connection of type $a \in S$ from node $s \in S$ to node $b \in B$, and each element $(a', (s, s')) \in (A \times (N \times N))$ determines the connection of type $a' \in B$ from node $s \in S$ to node $s' \in S$. Arcs from buyers to sellers are not allowed.

Also, a set of buyers connected to s_1 in network G' is denoted by $N^b(s_1, G')$ and a set of sellers buying access from s_1 is denoted by $N^s(s_1, G')$. Based on this notation we formally define feasible networks:

Definition 2. [Feasible network] A sharing network G' is feasible if the following conditions hold:

- for any two sellers $s_1 \in S$, $s_2 \in S$, if $(a, (s_1, s_2)) \in G'$, then $a \in N^b(s_2, G') \in B$;
- for $s_1 \neq s_2$ any connection $(s_2, (s_1, b)) \in G'$ if and only if $(b, (s_1, s_2)) \in G'$;
- if G' is different from a status quo network G_0, then for any seller $s_1 \in S$ and buyer $b \in B$, connection $(a, (s_1, b)) \in G_0$ preserves $(a, (s_1, b)) \in G'$ and $a = s_1$.

Given a status quo network G_0, a set of all feasible networks is denoted as $\mathcal{F}(G_0)$.

The first two conditions describe a double labeling procedure, which means that trade paths of affiliated nodes can be detected through the connections of sellers as well as connections of buyers. The formation of a link between sellers always corresponds to a formation of a link between one of the sellers and a buyer. Besides, according to the sharing rules, a seller may sell

large subset of cost functions, stable equilibrium in the bargaining game does not exist. Consequently, no sharing equilibrium exists for these cases.

[10]Since it is not possible to connect to isolated buyers via link sharing, we assume that they do not exist.

[11]The term "arc" is used instead of "link" to emphasize that an access from a seller to a buyer can be provided by different sellers and thus arcs may have different types.

an access only if he is connected to the buyer himself. The arc from one seller to another seller has type which is equivalent to the label of the shared buyer.

The third condition states that links cannot be sold ultimately. In other words, the number of connections may only increase, which in general, may or may not lead to an increase in trade volume.

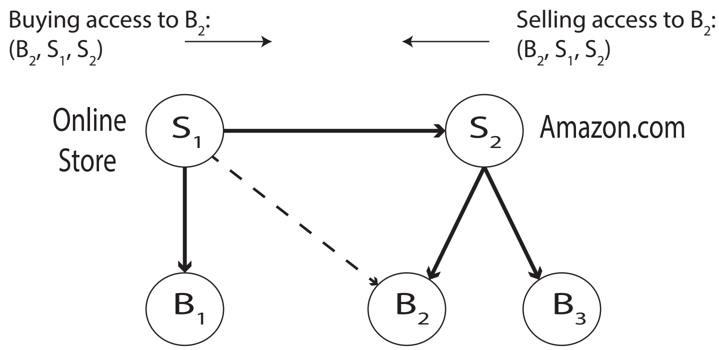

Figure 1: Network G': sharing access to buyers with a small unpopular store.

An example of network formation via sharing is the formation of online resellers, the feasible network is presented at Figure 1. The well-known online store Amazon is represented by node s_1, while a small online store is represented by node s_2. The two companies compete in the market of the same type of good (i.e. a cell phone[12]), but Amazon has incentives to provide a selling platform for the online store s_1 because of the large number of buyers that it has access to. The small store pays fee $t^2_{1,2}$, which depends on the sales volume of the online store. Under this rules, network G' is defined by

$$\text{initial connections } (s_1,(s_1,b_1)),(s_2,(s_2,b_2)),(s_2,(s_2,b_3)),$$

$$\text{connections formed as a result of collusion } (s_2,(s_1,b_2)),(b_2,(s_1,s_2)),$$

where the last two connections indicate that seller s_2 gets an access to buyer b_2 through seller s_1. This notation allows us to claim that sellers may trade goods with buyers not only through direct but also through indirect connections (if there is a path from a seller to a buyer).

3.3 The first stage: network formation

In the first stage of the game, sellers submit their bids similar to the model in Bloch and Jackson (2007) [13]: arbitrary seller s_i announces a set of links that will be shared and the corresponding sharing contract terms. Each contract, that s_i proposes, consists of the transfer function $t^k_{i,j}(\cdot)$ from seller s_i to seller s_j and a guaranteed transfer function $B^k_{i,j}(\cdot)$, which is the transfer from

[12]An unlocked phone HTC One 32GB Silver is sold by multiple online stores which are listed on Amazon.com, including Amazon itself and at least 30 more sellers. The stores sell exactly the same good without accessorizes and additional plan benefits.

[13]This paper considers contracts rather than simply prices, which means that sellers should agree on price and default correspondences, which are contingent on the emerged network and trade volumes.

seller s_i to seller s_j when the buyer of the link is insolvent. Both functions are contingent on the strategies of other players. Conclusively, seller s_1 submits bids in the form

$$[(b_k,(s_j,s_i)),t^k_{i,j}(\cdot),B^k_{i,j}(\cdot),]\ or\ [(b_k,(s_i,s_j)),t^k_{i,j}(\cdot),B^k_{i,j}(\cdot)],$$

where the first triple $(b_k,(s_j,s_i))$ captures a connection that seller s_i is willing to sell, and the second triple $(b_k,(s_i,s_j))$ is a connection that is being sold to s_i. Transfers may be positive as well as non-positive depending on the selling side. Transfers without actually selling the access are not allowed. [14]

We define a vector space Γ_i of functions from the set of networks of size $n\times m$ to the dual space R^2. The variableΓ_i denotes the set of all possible contracts that can be proposed by seller s_i. Then, in the first stage of the game, the action space of seller s_i is a product of the valid arc space and a corresponding contract: $((S\times(S\times B))\cap G_0)\times\Gamma_i$. The sets of possible contracts $\Gamma_1,\Gamma_2,...,\Gamma_n$ may be different across firms. For example, there may be a seller differentiation based on the maximum fixed cost that a firm can pay.

Functions $t^k_{i,j}(\cdot),B^k_{i,j}(\cdot)$ depend on the strategies of all sellers and buyers and may have various forms. For example, guaranteed transfer and transfer functions may be completely determined by a profit level that one of the sellers has: the functions may be constant or linearly dependent on the profit functions. The only requirements imposed on the contract terms are $B^k_{i,j}=t^k_{i,j}=0$ for normal profits, and $B^k_{i,j}\le t^k_{i,j}$ unconditional on the game outcome.

Connection $(b_k,(s_i,s_j))$ between arbitrary sellers s_i and s_j is formed if and only if

$$t^k_{i,j}+t^k_{j,i}\ge 0 \text{ and } B^k_{i,j}+B^k_{j,i}\ge 0$$

for any strategies of other players. If the amount paid exceeds the amount requested, the rest of money is wasted. However, it is clear that in the equilibrium money is never wasted.

To provide the intuitive association, we will refer to function $t^k_{i,j}(\cdot)$ as a full transfer, and to a function $B^k_{i,j}(\cdot)$ as a fixed cost or collateral. Then amount $t^k_{i,j}-B^k_{i,j}$ may be considered as a variable cost paid by seller s_i to seller s_j for the access to buyer b_k.

For simplicity, we will denote the states, when the strategies of other players are such that transfer $t^k_{i,j}$ can be paid in full, as $\Omega(s_i,s_j)=1$; otherwise, $\Omega(s_i,s_j)=0$ and only the fixed cost $B^k_{i,j}$ will be paid.

The limited liability condition is also imposed on sellers, which means that the some of total transfers they process is less than the profit that they get from selling or not selling the good.

3.4 The second stage: game on a network

Once network G' is formed in the first stage, sellers bargain with buyers via Nash bargaining mechanism: sellers and buyers submit their bids, and if the sum of bids exceeds zero, they trade.

We require equilibrium prices to be pairwise stable, which means that any seller and buyer cannot be better off by breaking the agreements or signing an alternative agreement with other traders. Suppose prices are proposed by buyers and sellers simultaneously, exactly like transfers in the first stage of the game, then any allocation of goods is pairwise stable if the offer, that is accepted, provides a higher utility level than the second best offers made to them. Based on

[14] A game with transfers unsupported by the link sharing may be considered as a collusion. Instead, in this paper, we consider only a legal form of cooperation.

this bargaining rule, multiple equilibria may arise: arbitrary chosen seller s_1 and buyer b_2 have no incentives to deviate from any price $p(s_1, b_2)$ that exceeds the maximum price that can be offered by buyers $N^b(s_{1,}G')$ and is inferior to the minimum price offered by sellers $N^s(b_2, G')$. To guarantee the uniqueness and validity of beliefs in the multiple stage game, we say that among all equilibrium prices $[\underline{p_{12}}, \overline{p_{12}}]$ defined by the disagreement point, the equilibrium that emerges is $p(s_1, b_2) = (1 - z)\underline{p_{12}} + z\overline{p_{12}}$. This equilibrium selection is consistent with the Rubinstein bargaining mechanism, when traders make alternative offers next period if they disagree on the price, and parameter $z \in [0, 1]$ is determined by the time discount factor. For the egalitarian rule, z would be equal0.5. Parameter z also characterizes the bargaining power that sellers have relative to buyers. The same approach to equilibrium selection is used in Elliott (2012) and Corominas-Bosch (2003).

The multiplicity of equilibria under this selective procedure is still possible when, for example, two buyers with the same values compete for the good. However, independent on the allocation of the good, buyers will get zero utility. It happens because the utility from not having the good is assumed to be zero, while utility from paying the maximum value as a price also delivers utility of zero.

3.5 Payoffs.

Suppose that G' is an equilibrium network formed in the first stage of the game, while $\{t^b_{i,k}, B^b_{i,k}\}_{i,k,b}$ and $\{p(s_i, b_k)\}_{i,k}$ are the sets of equilibrium transfers and prices. Without loss of generality, the final payoff that players s_i and b_j get is the difference between the value and the sum of transfers and prices that they pay:

$$V_{s_i}(t,p) = -v(s_i) - \sum_{s,b_k:(s,(s_i,b_k))\in G'} p(s_i, b_k) - \sum_{b,s_k:(b,(s_i,s_k))\in G'} t^b_{i,k} I(\Omega(s_i, s_k) = 1) - \tag{1}$$

$$- \textstyle\sum_{b,s_k:(b,(s_i,s_k))\in G'} B^b_{i,k} I(\Omega(s_i, s_k) = 0)$$

$$V_{b_j}(t,p) = v(b_j) - \sum_{s,s_k:(s,(s_k,b_j))\in G'} p(b_j, s_k), \tag{2}$$

where $I(\cdot)$ is an indicator function.

If the insolvency of the seller happens, it leads to a default and only an amount of fixed cost is paid to creditors. The bankruptcy of a seller is announced when he is unable to pay the creditors back given the equilibrium prices:

$$\textstyle\sum_{b,s_k:(b,(s_i,s_k))\in G'} t^b_{i,k} + v(s_i) + \sum_{s,b_k:(s,(s_i,b_k))\in G'} p(s_i, b_k) \geq 0.$$

The set of fixed costs should be lower enough, such that the following inequality is satisfied given the variation in the strategies of other sellers:

$$\textstyle\sum_{b,s_k:(b,(s_i,s_k))\in G''} B^b_{i,k} + v(s_i) + \sum_{s,b_k:(s,(s_i,b_k))\in G''} p(s_i, b_k) \leq 0.$$

We assume that the set of valid contract is restricted to the contracts satisfying the inequality above.

3.6 Equilibrium refinement

The appropriate concept of equilibrium for the dynamic game is a subgame perfect equilibrium, which eliminates an obligation for the selling party to avoid trade with the shared buyer. In other words, an agreement between two sellers may not enforce one of them to sell the link, the contract may only provide access to a seller using the connections of another seller. This situation is possible when links are rival but non-excusable. One of the examples of this situation is when links in a bargaining network formation game are used to model the acquaintances or business connections on the markets with high search costs. Another example is when buyers have binary preferences for some particular technology or brand and existence of a link is equivalent to a patent or a presence of some essential brand characteristics. To emphasize that the contracts are not restrictive for the selling side, we use the terminology "sharing a link" instead of "selling a link".

3.6.1 Pairwise stable equilibrium in the bargaining subgame

First the bargaining game on the network is considered. The pairwise stable equilibrium in the subgame is defined in the following way:

Definition 3. [Pairwise stable equilibrium in the bargaining subgame] Externally given set of transfers $t = (t_1, t_2, ..., t_n)$, guaranteed transfers $B = (B_1, B_2, ..., B_n)$[15], and a status quo network G_0 are sufficient to define emerged network $G' \in \mathcal{F}(G_0)$. In a corresponding bargaining subgame, a set of strategies

$$p_{s_i} : (S \times (s_i \times N^b(s_i, G'))) \to \Re$$

$$p_{b_j} : (S \times (N^s(b_j, G') \times b_j)) \to \Re$$

and payoffs defined in (1), (2) constitute a pairwise stable Nash equilibrium (PSNE) if each trader is worse off by not trading and there does not exist a pair of players (s_i, b_j) and corresponding actions $p^o_{i,.}, p^o_{j,.}$ such that

$$V_{s_i}(t, p_{s_1}, ..., p^o_{s_i}, ..., p_{s_n}, p_{b_1}, ..., p^o_{b_j}, ..., p_{b_m}) \geq V_{s_i}(t, p_{s_1}, ..., p_{s_i}, ..., p_{s_n}, p_{b_1}, ..., p_{b_j}, ..., p_{b_m})$$

$$V_{b_j}(t, p_{s_1}, ..., p^o_{s_i}, ..., p_{s_n}, p_{b_1}, ..., p^o_{b_j}, ..., p_{b_m}) \geq V_{b_j}(t, p_{s_1}, ..., p_{s_i}, ..., p_{s_n}, p_{b_1}, ..., p_{b_j}, ..., p_{b_m})$$

and one of the inequalities is strict.

The main difference from the definition of Bloch and Jackson (2007) is the ability of two sellers to change all their bids simultaneously. The concept of pairwise equilibrium in Bloch and Jackson (2007) assumes that a player may deviate by changing the bids or by changing only one bid. However, if according to the rules of the game only one active connection is possible, it is reasonable to assume that simultaneously by signing a new trade agreement with b_j, seller s_i may want to break down the agreement with the previous business partner b_i. The pairwise Nash stability is a natural extension of the strong stability concept, described in Gilles and Sarangi (2004), extended on the network formation with transfers.

[15]For simplicity, t_i denotes the set of transfers between seller s_i and other sellers.

3.6.2 Subgame perfect equilibria with pairwise stable Nash agreements

Similar to the equilibrium concept used in the subgames, we define the feasible equilibrium concept for the whole game:

Definition 4. [Subgame perfect equilibrium with pairwise stable Nash agreements (SPPSNE)] Externally given a status quo network G_0, the set of contracts $(t = (t_1, t_2, ..., t_n)$,$B = (B_1, B_2, ..., B_n))$, trade agreements and a vector of prices $P_f(t_1^{'}, B_1^{'}..., t_i^{'}, B_i^{'}..., t_j^{'}, B_j^{'}...)$ defined for all possible contracts $(t_1^{'}, B_1^{'}..., t_i^{'}, B_i^{'}..., t_j^{'}, B_j^{'}...)$ form a subgame perfect equilibrium with pairwise stable Nash agreements if
i) prices form a pairwise stable Nash equilibrium in each subgame;
ii) transfers form a pairwise stable Nash equilibrium in the network formation game played at $t = 1$, which means that sellers benefit from sharing and there does not exist a pair of players (s_i, s_j) and corresponding contracts $((t_i^0, B_i^0)$, $(t_j^0, B_j^0))$ with $(t_{i,j}^0, B_{i,j}^0) = (-t_{j,i}^0, -B_{j,i}^0)$ such that

$$V_{s_i}(t_1, B_1..., t_i^0, B_i^0..., t_j^0, B_j^0..., P_f) \geq V_{s_i}(t_1, ..., t_i, B_i..., t_j, B_j...., P_f)$$

$$V_{s_j}(t_1, ..., t_i^0, B_i^0..., t_j^0, B_j^0...., P_f) \geq V_{s_j}(t_1, ..., t_i, B_i..., t_j, B_j..., P_f)$$

and one of the inequalities is strict.

3.6.3 Equilibrium existence

The existence of the pairwise equilibria is not guaranteed. From the previous literature, it is known that network formation game with transfers does not always sustain an equilibrium.

Besides, the sharing game cannot be characterized as a game with non-positive or non-negative externalities, so the specific results of Bloch and Jakson (2007) cannot be applied.

Finally, the game does not have a potential function, which eliminates the possibility of solving the model using maximum optimization techniques. So existence cannot be proved by some general results and should be examined specifically for this model.

4 Homogeneous sharing networks

In this part of the paper, the production costs are assumed to be homogeneous and equal zero. Homogenous buyers are willing to pay no more than one unit of currency for the good. The homogeneous assumption helps to observe the status quo network effect on the final outcome. The heterogeneous case will be considered in the next section of the paper.

4.1 Network decomposition in the homogeneous bargaining game

From the paper of Corominas-Bosch (2004) it follows that any bipartite network can be decomposed into the subnetworks of three different types: G^s, G^b, G^e. Subnetwork of a network G is called of type $G^s(G)$ if there are more sellers than buyers in this network and all buyers can be matched with sellers in this subnetwork. Subnetwork of a network G is called of type $G^b(G)$ if there are more buyers than sellers in this network and all sellers can be matched with buyers in this subnetwork. A subnetwork is called of type $G^e(G)$ if there is equal number of sellers and buyers and all of them can be matched. The condition on the maximum bipartite matching in a subnetwork is equivalent to the Hall's criteria.

Conjecture. *(Hall's criteria)*

- For the set of n sellers S and m buyers B connected via a subnetwork of type $G^b(G)$ (or $G^e(G)$) with $n \leq m$, there exist a matching saturating the set of sellers if and only if any subset W of sellers of size $k < n$ is connected to more than k buyers: $|W| \leq |N^b(W,G)|, \forall W \subset S$.
- For the set of n sellers S and m buyers B connected via a subnetwork of type $G^s(G)$ (or $G^e(G)$) with $n \geq m$, there exist a matching saturating the set of buyers if and only if any subset W of buyers of size $k < m$ is connected to more than k buyers: $|W| \leq |N^s(W,G)|, \forall W \subset B$.

It is known that the stable outcome in the homogeneous bargaining game always corresponds to the maximum matching in a given network. From the decomposition it follows that without sharing, the stable outcome is such that sellers and buyers in $G^s(G_0)$ get zero and one correspondingly, while sellers and buyers in $G^b(G_0)$ get one and zero correspondingly.[16]

Notice that the payoffs of agents are independent of the volume of trade. Indeed the multiplicity of equilibria exists when an agent is indifferent between multiple trade agreements or between zero profit and non-trading. Nevertheless, independent of the equilibrium selection, the agents with no bargaining power always get no benefits from trade (their payoff is zero). The split of trade surplus between a buyer and a seller in $G^e(G_0)$ is pairwise stable if it provides traders with the payoff higher than the second best offer. In the homogeneous case, it can be shown that pairwise stable prices in $G^e(G_0)$ with the equilibrium selection proposed above are always $z \in [0; 1]$.

The example of a status quo network G_0 is provided on Figure 2, the unique decomposition is also shown as clouds of types G^b, G^s and G^e. The possible trade agreements are indicated by red fat lines. There are multiple equilibria that satisfy pairwise stability in G_0: seller s_1 is always indifferent between trading with b_1 or b_2, as well as b_5 is indifferent between trading with s_4 and s_5. However, the benefits from trade are the same for all equilibria (see numbers next to the nodes). We may observe that connectivity in the network is insufficient for the sellers in G^e and G^s to extract full benefits of trade. If s_6 shares market with s_5, the new network G' can be formed. In the bargaining game played on G', sellers increase their payoffs relative to the ones on network G. Again, the matching is not unique, but the payoffs are unique. It is also clear, that the maximum volume of trade is achieved when the link is added.

From this example, the benefits of adding links becomes clear; however, under the strategic link formation, network G' is not stable. To find the stable sets, we consider the special and the more general cases in the subsections that follow.

4.2 Networks consisting of subnetworks of types G^s and G^e

The interpretation for the model of homogeneous networks can be easily provided: sellers of type $G^b(G_0)$ represent well-established firms with good reputation, sellers of type G^e represent small

[16]The proof of this fact is given in Corominas- Bosch (2004). This result was also verified in the lab experiment conducted by Charness, Corominas-Bosch, and Frechette (2007)

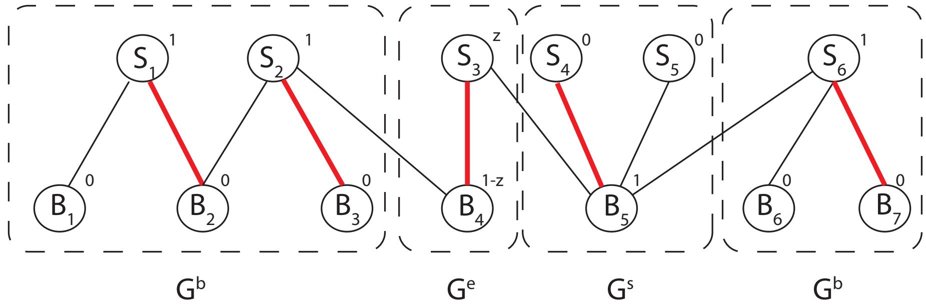

Figure 2: Network decomposition of status quo network G_0.

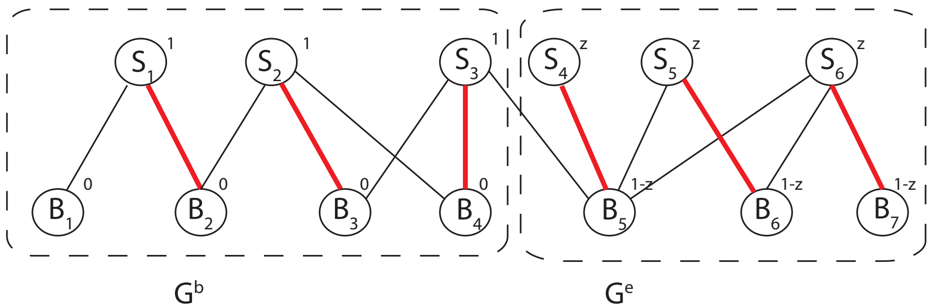

Figure 3: Network decomposition of network G'.

firms that earn enough profit to survive on the market, but do not have enough bargaining power to charge maximum prices, finally sellers of type G^s are new entrants. All firms have the same production costs, but different reputation and different prevalence on the market. It is often the case that size of production is limited from above and direct market expansion is costly, so well-established firms prefer franchising as a form of market expansion. Under this explanation, we interpret seller-buyer arcs as brand loyalty, and seller-seller arcs as franchising contracts. This example or other applications discussed in the introduction, have a special case when a status quo network has only sellers of types G^b and G^e. For the franchising model, network formation may be considered as converting existing sellers into the franchising agents, which leads to a monopolization of the market. The more specific model is a model of business expansion for one particular firm. The equilibrium prices and contract terms for these specifications are described below.

4.2.1 Link sharing between one seller of type $G^b(G_0)$ and multiple sellers of type $G^e(G_0)$: franchising as a form of market expansion

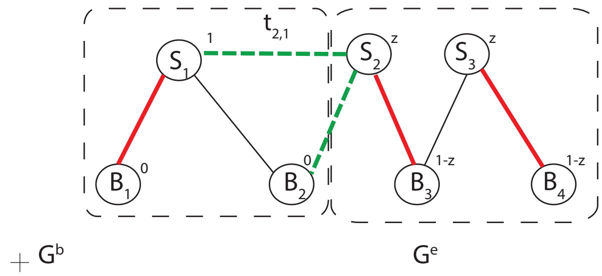

Figure 4: Example: s_2 buys access to b_2 to increase his bargaining power.

It is easy to understand the model using the example with one seller $s_1 \in G^b(G_0)$ and two sellers $s_2, s_3 \in G^e(G_0)$ (see Figure 4). Seller s_1 attracts sufficient number of sellers, while sellers s_2 and s_3 face a tough competition. If s_2 decides to join the franchise business network of s_1, he gains the loyalty of new buyers, while seller $s_3$benefits from the decrease in competition. One of the equilibria is when sellers share access with each other for free. Sellers s_2 and s_3 have no incentives to increase the price, while seller s_1 cannot resell the access at a higher price once the contract with s_2 is signed. So there is no Nash or pairwise deviations that increase the welfare of sellers.

There is another set of equilibria that are not trivial. When one of the sellers in G^e makes a positive transfer to s_1(suppose it is seller s_2), another seller's best response is to free ride. To price the access, we recover that the benefit that seller s_2 gets is $1-z$, while s_1 is not affected by this network formation. The sellers have no incentives to breach if and only if $t_{2,1} \in [0, 1-z]$.

In addition, the amount of guaranteed transfer is not important in this case, as soon as $t_{2,1} \geq B_{2,1}$, because the emerged network is of type $G^b(G)$ and the sellers always extract all endowment from the buyers. Seller s_1 has no incentives to underprice seller s_2, because of limited production and availability of idle buyers.

In summary, the second type of equilibria agreements is the following: s_1 provides seller s_2(or s_3) with access to one of the buyers for the transfer $t_{2,1} \in [0, 1-z]$, while seller $s_3(s_2)$ free rides. Sellers gain full bargaining power in the market and buyers pay full price for the good.

A more general result is given for the case when seller s_1 may expand to several locations:

Proposition 1. *In a network with one seller dominating the local market (s_1 of type $G^b(G_0)$), and other sellers facing moderate competition ($s_2, s_3, ..., s_N$ of type $G^e(G_0)$), there are two sets of pairwise stable equilibria:*

(1) Seller s_1 of type G^b shares access with some sellers free of cost, other sellers freely get access from those who already gained it. Multiple or zero intermediaries may be created.

(2) A tree of intermediaries is created, such that there are no two sellers in the tree from the same sub-network of G_0 and each non-terminal seller of the tree is transferring a non-negative amount to the seller above in the hierarchy. Being a member of the tree, each seller transfers at least the amount that was transferred to him.

Contracts with only low guaranteed transfers are possible $B_k \leq 1-z$. Sellers contribute contribute a non-negative amount to the final transfer: an arbitrary terminal seller s_k in the

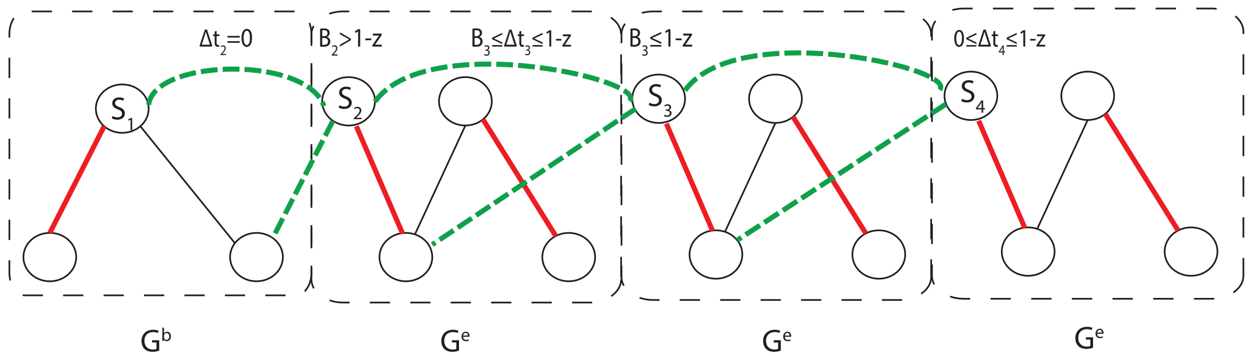

Figure 5: The equilibrium network in the franchising sharing game

tree transfers amount $\Delta t_k = t_{k,k-1} \in [0, 1-z]$*, while every next seller* s_l *contributes* $\Delta t_l = t_{l,l-1} - \sum_i t_{i,l} \in [B_l, 1-z]$ *to the amount that was transferred to him and processes it forward.*

When sellers have more bargaining power than buyers ($z \geq \frac{1}{2}$)*, only equilibrium of type 1 exists. When buyers have more bargaining power, both types of equilibria are possible.*

Proof. See Appendix.

Notice that intermediaries in the tree do not get direct profit from reselling, and do not benefit from their position in the tree. Only the last seller s_N in the chain has the privilege because he has no restrictions on the transfer from below. In this set of equilibria, all sub-networks of type G^e upgrade to G^b and sellers gain full bargaining power. The condition for the net transfers to be above the guaranteed transfer may be interpreted as the condition for the intermediary to contribute a significant portion in the total stream of transfers, so that other firms support the sustainability of the intermediary. Intermediaries with the small monetary inflow or with a large fixed cost B_k, will contribute low risk to the system and finally will be held up by one of the sellers in the chain.

The part of the equilibrium network is presented at Figure 5. Suppose sellers that are connected to s_1 are brand sensitive and travel to the specialized store, while others are not brand sensitive and buy goods from the stores which are close to them. Sellers s_2,s_3,.... experience tough competition, because many local consumers switched to bargaining with seller s_1. Seller s_1 can efficiently produce only one unit of good, that is why he has incentives to form a tree of intermediaries. In the equilibrium, the franchising network will include only few representatives on each local market. The intuition behind this fact is that costly franchise license is not needed when the competitiveness of the local market becomes low enough. The contributions of the intermediaries are non-negative and depend on the guaranteed transfer B_i. Firms that can guarantee a larger part of the transfer in case of emergency, get access for free. Thus the stability of an intermediary is as important as the transfer that it pays.

4.2.2 Multiple sellers of type G^b

When there are multiple sellers of type G^b, any equilibrium with positive transfers has a profitable deviation: since randomply chosen sellers s_{1a}, $s_{1b} \in 0$ bear no cost of sharing a link, they will always underbid each other, unless transfer is zero. We also conclude that under zero transfers, sharing network may have any structure.

4.3 Networks consisting of subnetworks of types G^s, G^b G^e: large markets with new entrants

We consider a network with three different subnetwork types. Sellers of type G^s may be interpreted as new entrants, because initially they either trade at a zero price or do not trade at all. We also assume that there is more than one network of each type. Then the equilibrium outcome can be determined based on the initial network structure.

Proposition 2. *If* the excess of buyers in the market is greater than number of monopolized sellers in the market $N^b(G_0, G_0) - N^s(G_0, G_0) > N^s(G^b, G_0)$, *then there exist a pairwise stable equilibrium when monopolized sellers freely share access with other sellers and stop sharing when they have at least one non-trading buyer in the local market. All sellers extract full bargaining benefits. Full efficiency is achieved with the complete redistribution of wealth to the seller's side.*

Proof. See Appendix.

The proposition above states that when there are sufficiently few new entrants, a pairwise stable equilibrium exists. Besides, the price of sharing is zero at any state of the game. The following theorem states that when there are more sellers than buyers, the set of equilibria is sufficiently larger and includes equilibria with non-zero transfers.

Proposition 3. *If* the number of buyers is at most equal to the number of sellers $N^b(G_0, G_0) \leq N^s(G_0, G_0)$, *then there exist a pairwise stable equilibria when monopolized sellers share access with other non-trading sellers for transfers* $|t_{i,j}| \in [1-z-B(t_{i,j}), z]$ *and* $\{B_{i,j} \leq min(z, 2z-1)\}_{i,j}$ *for* $s_i \in G^b(G_0)$ *and* $s_j \in G^s(G_0)$. *Sellers change their type to* G^e *if possible. Full efficiency is achieved and sellers and buyers share market surplus according to weights z and 1-z. When number of buyers and sellers is equal, a transfer from* $s_i \in G^s(G_0)$ *to* $s_j \in G^b(G_0)$ *equals* $|t_{i,j}| = 1 - z - B_{i,j}$.

Proof. See Appendix.

It also becomes clear that markets with exceeding number of sellers do not require strong government regulation because the surplus is divided relatively equitably. The employment market, for instance, has exactly the structure described above.

Proposition 4. *When* $0 < N^b(G_0, G_0) - N^s(G_0, G_0) < N^s(G^b, G_0)$, *pairwise stable equilibrium does not exist.*

Proof. The result of the theorem follows from the proofs of propositions 2 and 4.

Corollary 1. *If a subgame perfect stable equilibrium exists in the sharing game, the emerged network is Pareto efficient and the volume of trade is equivalent to the volume of trade in the Walrasian equilibrium for the complete network.*

5 Heterogeneous sharing networks

In this section, the assumption of traders being homogeneous among groups is relaxed. Sellers as well as buyers may value good differently. As we mentioned earlier, for the markets with network structure, there is no unique price. Additionally, not every link between traders will be actively used in bargaining, which is the case due to different bargaining positions of traders and a property of indirect preferences having a bliss point. To describe the equilibrium in the heterogeneous sharing game,we will need to distinguish between active and non-active arcs and traders.

Definition 5. For a given equilibrium network $G = (N \times (A \times A))$, a group of active traders $N_A(G)$ is defined as a set of nodes actively involved in bargaining. The rest of players can be decomposed into the subsets $N_P(G)$ and $N_N(G)$, where $N_P(G)$ is formed by nodes being best alternative offers for somebody, and $N_N(G)$ consists of non-trading players that have no effect on the prices of others. Eventually, for any equilibrium network G, set of nodes can be presented as a union of three subsets $N = N_A(G) \cup N_P(G) \cup N_N(G)$.

It is clear that for each equilibrium network, the node decomposition is unique. Based on the node representation, the following proposition characterizes the equilibrium network.

Proposition 5. *In the subgame perfect pairwise equilibrium, if an emerged network G' is decomposed into subnetworks $N_A = N_A(G')$, $N_P = N_P(G')$, and $N_N = N_N(G')$, the following properties follow:*

a) all non-trading buyers N_N have lower values than passively trading buyers:

$\forall b_1 \in N_N \cap B$ *and* $\forall b_2 \in N_P \cap B$ *it is always the case that* $v(b_1) \leq v(b_2)$*;*

b) actively trading buyers value good higher than passive buyers

$\forall b_1 \in N_P \cap B$ *and* $\forall b_2 \in N_A \cap B$ *it is always the case that* $v(b_1) \leq v(b_2)$*;*

c) actively trading sellers produce at a lower cost than non-trading sellers

$\forall s_1 \in N_A \cap S$ *and* $\forall s_2 \in G_P \cup G_N \cap S$ *it is always the case that* $v(s_1) \leq v(s_2)$*;*

Proof. See Appendix. □

Similar to the homogeneous case we can prove that if a pairwise stable equilibrium exists, it is efficient. Efficiency is considered in terms of total market surplus, but the Pareto efficiency concept is equivalent to it in this model. We may use the simple demand and supply curves to illustrate the Walrasian equilibrium.

Proposition 6. *The network effect may be completely eliminated in the model with link sharing: in the subgame perfect pairwise stable equilibrium, the total social surplus is equivalent to the Walrasian total surplus. Besides, sellers and buyers trading in the network market are equivalent to those trading in the market with complete network structure.*

Proof. ◀We define volume of trade Q^{walr}on the intersection of demand and supply curves (see Figure 6 for details). From the propositions above, it follows that the set of active traders is a series of all agents from the left to some threshold Q^{tres}. First, assume that $Q^{tres} < Q^{walr}$. Then it follows that there exists a seller s_1 connected to some buyer b_1 with $v(s_1) < v^{walr} < v(b_1)$. If traders s_1 and b_1 are connected, they deviate from the equilibrium and trade, which leads to contradiction. If the traders are not connected, since network has only one component in it, buyer b_1 is connected to some other seller s_2. Then the profitable deviation for seller s_2 always exists. If the option to trade with b_1 is not possible, seller s_2 sells access to seller s_1 do not involve into bargaining with b_1. The existence of the pairwise deviation contradicts the assumption that network that we consider is stable. It means that in the stable equilibrium, trade volume is at least as low as in the Walrasian case.

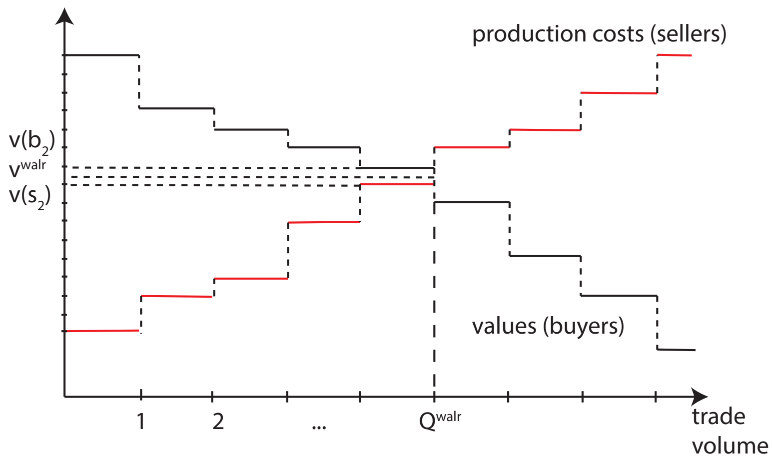

Figure 6: Trader's values and Walrasian equilibrium.

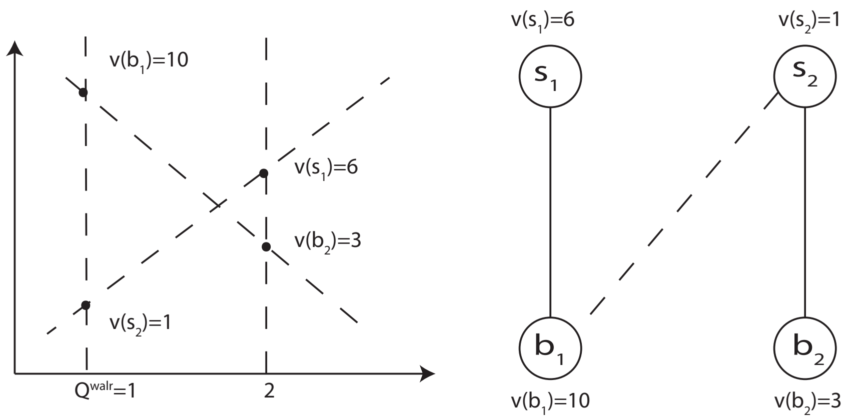

Figure 7: Example of a market with network structure.

In fact total surplus is Q^{walr}. The proof is that if there are two pairs with one seller and one buyer being to the left side of Q^{walr} and other two traders being to the right side, seller with the higher cost shares access to his buyer and do not bid any price. This collusion increases pairwise surplus and leads to non-stability of equilibria. This thought example proves that $Q^{tres} \leq Q^{walr}$. □

The intuition behind the proof can be gained from the example presented on Figure 7. Suppose, there are only two buyers and two sellers with the values shown at the Figure 8. If network is complete, seller s_2 trades with buyer b_1 at price $p_{2,1} = 6z + 3(1-z) = 3 + 3z$ and gains surplus $2 + 3z$. Given network $G_0 : (s_{1,}(s_1, b_1)), (s_{2,}(s_2, b_2))$, sellers and buyers fix prices $p_{1,1} = 10z + 6(1-z) = 6 + 4z$ and $p_{2,2} = 3z + 1(1-z) = 1 + 2z$ and together gain surplus $3z$. If seller s_1 sells access to b_1 and does not bid, the equilibrium price is $p_{2,1} = 10z + 3(1-z) = 3 + 7z$ and seller's surplus is $2 + 7z$. When the network contains one component, total market surplus is 9, whereas when it contains two components, total market surplus is 6. So complete network structure makes sellers better off when they form coalition: the total social surplus increases from 6 to 9 with the increase in seller's surplus from $3z$ to $2 + 7z$ and change in buyer's surplus from $6 - 3z$ to $8 - 7z$.

6 Conclusion and possible extensions

The main purpose of this paper is to analyze how the cooperation between sellers may eliminate the barriers created by a network structure of the market. The collusive behavior between sellers is modeled as a link sharing process. Sellers are allowed to trade with each other prior to the bargaining stage. When network is built, sellers and buyers bargain for the product. The question that was raised is how the information sharing (access sharing) affects the network structure of the market. Surprisingly, in the general heterogeneous model, sharing always leads to a maximum increase in efficiency when an equilibrium exists. The more interesting question is how the market surplus will be reallocated from buyers to sellers (or from sellers to buyers). For the simplified version of the model it is shown that when number of buyers in the network is large, sellers extract full benefits from trade by matching non-trading agents with each other as well as increasing seller's bargaining power. When number of sellers and number of buyers are relatively equal, no equilibrium exists. Alternatively, when market has a number of new entrants exceeding number of buyers, existence of equilibria for any type of network may be guaranteed by the bargaining privileges of sellers over buyers and a low fixed cost level. Exactly for these specification of parameters, the bargaining outcome will be most equal: monopolized sellers will sacrifice their bargaining power to get a share of benefits from the additional product being sold.

The special case of the homogeneous model is considered, which we refer to as a business expansion model for the firm. Additional to the equilibrium where the firm earns no profit from business expansion, another, non-trivial, equilibrium exists. Firm collects payments from the tree of intermediaries. It is shown that the position of seller in the tree as well as the rent depend on the guarantee that firm is willing to provide.

Further extension of the model may be in relaxing the main assumptions, such as linearity of trader's preferences and unit demand. The future work also includes comparison of the models with access sharing and access selling. Finally, cooperative behavior may be extended to aggressive collusive behavior, such as sharing financed by a group of firms. This network formation rule could eliminate positive externality problem and increase profits of the supplier.

The main theoretical contribution of this paper is an extension of the pairwise Nash equilibrium in the network formation games with transfers. The following modification of the classic approach has been made: to form a link two sides sign a contract, which may be defined as a function, rather than a number. The consistency of two proposals should be present in order for contract to be signed. The pairwise stability with transfers is applied to a multiple-stage game. We think that a more general theoretical definition of the dynamic pairwise stable equilibrium with contracts should be provided in the future for general network formation games. It is commonly the case in reality that a business connection between two agents is formed based on the contract contingent on the future state of the world. So theory built as an extension of this paper should become a solid base for the future research.

The paper also leaves room for the policy implications, which may include taxation of the sharing activity as well as restrictions on the level of fixed cost. A question that can be asked in the future is the existence of an efficient stable equilibrium when the policy is implemented.

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Appendix

Proof of Proposition 1

If there are more than two sellers in a sub-network of type G^e and $N > 1$ subnetworks of type G^e exist, the intuition is similar to the example in the subsection 6.1. With cooperation among sellers, there is exactly one seller in each sub-network, paying for the access, the rest of sellers free ride. Without loss of generality, we say that the set of sellers paying for the access is $(s_2 \in G_2^e, ..., s_k \in G_k^e, ..., s_N \in G_N^e)$ (see Figure 8 for an example).

Now suppose that at least two sellers (s_k and s_{k+1}) buy access directly from seller s_1. Then one of them (s_{k+1}) has always incentives to deviate and get access from s_k at a lower price unless price is zero. The only case when sellers are indifferent between breaching and keeping the contract is when all sellers connected to s_1 are transferring zero. In this case it becomes costless to get an access from s_1, so all agreements that G^e sellers form with each other can only be of a zero transfer. As a result of link sharing with zero transfers, all G^esellers upgrade their type to G^b. The mapping of sharing contracts is not so important in this case; more than that, any network of pairwise agreements formed by sellers $(s_1, s_2, ..., s_N)$ will support this equilibrium.

To find equilibria with non-zero transfers, we start with only one seller buying an access from s_1 (for example in Figure 8 $s_2 \in G_2^e$ transfers $t_{2,1} > 0$)[17]. Suppose also that there is another seller s_3 getting access through s_2. If s_2 can cover the cost of a new link and stay profitable in the deal with $0 \leq t_{2,1} \leq 1 - z$, he accepts any type of agreement $t_{3,2} \geq 0$ from s_3 (use Figure 8 for the graphical representation). Seller s_1 also accepts any agreement terms from s_3, because it does not affect the solvency of his current partner s_2. We know that necessary condition for stability is s_3 getting access through s_2, so to eliminate strong incentives of s_3 to deviate to the contract with s_1, we require $t_{3,2} = 0$. By induction we know that once one seller gets an access at zero price, others also pay zero for the access.

If $(1 - z) < t_{2,1} \leq 1$, at least two sellers needed for s_1 to share. Nevertheless, in this case equilibrium does not exist, because s_3 can always breach and cooperate with $s_1$at a lower price. Seller s_1 is willing to hold up, because $t_{2,1}$ will be repaid anyway from the funds of s_1. Thus for stability we require at least $t_{2,1} > 1$. When $t_{2,1} > 1$ and the transfers of two sellers is enough to cover $t_{2,1}$, they have no incentives to breach if net transfer is less than $1 - z$. Sellers s_1 and s_3 do not hold up on $s_2$if net transfer Δt_2 is greater than the fixed cost $B_{2,1}$. Then the necessary condition for the equilibrium with positive transfers is

$$B_{2,1} \leq 1 - z,$$

and we require

$$B_{2,1} < \Delta t_2 \leq 1 - z, \text{ where } \Delta t_2 = t_{2,1} - t_{3,2}$$

$$\Delta t_3 \leq 1 - z, \text{ where } \Delta t_3 = t_{3,1}$$

If there are at least three subnetworks of type G^e and $t_{3,1} \leq 1 - z$, the leading seller of subnetwork G^e can bargain with s_2 and s_3 for the access and finally decrease the transfer to $t_{4,i} = 0$. The rest of sellers get access for free.

We generalize the case for $t_{2,1} > 1 - z$, with intermediary s_k getting an access from s_{k-1} and transferring $t_{k,k-1}$ to show that equilibria with more than two stages of intermediaries are possible. Being a member of the tree, each seller s_k transfers at least the amount that was

[17] The upper index m of the transfer variable $t_{k.l}^m$ is omitted for simplicity.

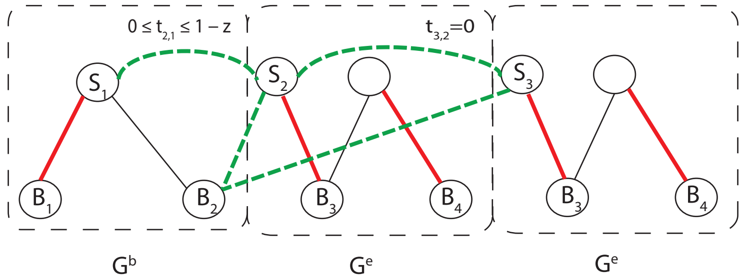

Figure 8: Network decomposition of emerged network G'.

transferred to him. So there is also no player in the tree who gets a direct profit from reselling. Otherwise, seller s_{k+1} will jump over s_k and cooperate with s_{k-1} and other sellers on the same tree level at a price lower then it is paid to s_k. Thus an equilibrium set of transfers needs to satisfy

$$0 \leq t_{k,k-1} - \sum_{l=1}^{N} t_{l,k} \leq 1 - z \text{ for } k = 2, ..., K$$

$$t_{2,1} = -t_{1,2}$$

For simplicity we denote the net transfer of seller s_k as $\Delta t_k = t_{k,k-1} - \sum_{l=1}^{N} t_{l,k}$. Then the condition above is equivalent to $0 \leq \Delta t_k \leq 1 - z$. It is obvious that for the equilibrium with the tree of K sellers, the total profit of agent $s_1$cannot exceed $K(1-z)$ but it can be less, which means that the same profit for seller s_1 may be provided by a different number of intermediaries.

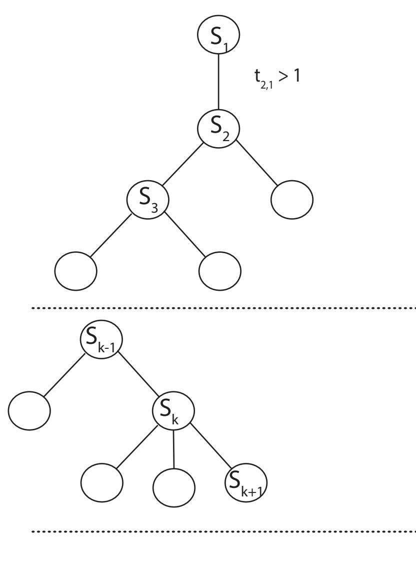

Figure 9: Formation of a chain of resellers

To control for a hold up problem in the contracts with non-zero transfers, we start with the conditions on transfers to eliminate incentives for sellers s_{k-1} and s_{k+1} to trade apart from s_k with transfer $\hat{t}_{t+1,t-1}$. When a hold up problem arises, seller s_{k-1}undercuts s_k but nevertheless keeps the contract with s_k open (see Figure 9 for the tree of intermediaries). Additional to the transfer $\hat{t}_{t+1,t-1}$ from s_{k+1}, seller s_{k-1} gets a full payment from s_k if s_k is able to repay it, otherwise he gets the amount of deposit $B_{k,k-1}$ in case of default. We may say that s_{k-1}gets the following payment from s_k

$$x_{k,k-1} = \begin{cases} t_{k,k-1}, if & \sum_{l=1}^{N} t_{l,k} - t_{k+1,k} + 1 \geq t_{k,k-1} = \sum_{l=1}^{N} t_{l,k} + \Delta t_k \\ B_{k,k-1}, if & \sum_{l=1}^{N} t_{l,k} - t_{k+1,k} + 1 < t_{k,k-1} = \sum_{l=1}^{N} t_{l,k} + \Delta t_k \end{cases}$$

which can be simplified to

$$x_{k,k-1} = \begin{cases} t_{k,k-1}, if & \Delta t_k \leq 1 - t_{k+1,k} \\ B_{k,k-1}, if & \Delta t_k > 1 - t_{k+1,k} \end{cases}$$

Then seller s_{k-1}has incentives to deviate from the equilibrium if and only if

$$\hat{t}_{t+1,t-1} + x_{k,k-1} \geq t_{k,k-1}$$

Seller s_{k+1}has incentives to breach the contract with s_k and cooperate with s_{k-1} if and only if

$$\hat{t}_{t+1,t-1} \leq t_{k+1,k}$$

.

Thus we can say that transfers are pairwise stable when

$$t_{k.k-1} - x_{k,k-1} \geq t_{k+1,k}$$

or using the definition of $x_{k,k-1}$ we can formulate the condition on pairwise stability in terms of transfers $(t_{k,k-1}, t_{k+1,k})$ and net transfer Δt_k :

$$\text{if } \Delta t_k + t_{k+1,k} \leq 1 \text{ then } t_{k+1,k} \leq 0$$

$$\text{if } \Delta t_k + t_{k+1,k} > 1 \text{ then } t_{k,k-1} - t_{k+1,k} \geq B_{k,k-1}$$

$$0 \leq \Delta t_k \leq 1 - z$$

.

From the conditions above, it immediately follows that $t_{k+1,k} \geq z$ unless $t_{k+1,k} = 0$. If layer $k+1$ is the last layer paying non-zero transfer, then

$$z < t_{k+1,k} = \Delta t_{k+1} \leq 1 - z$$

So condition $z < \frac{1}{2}$ is a necessary condition for the non-zero transfer equilibrium to exist. ▶

Proof of Proposition 2

◄

Suppose without loss of generality $s_1 \in G^b(G_0)$, $s_2 \in G^e(G_0)$ and $s_3 \in G^s(G_0)$ and network G' is formed in the stable equilibrium, such that $s_1 \in G^b(G')$. Then the following statements are true.

If $s_1 \in G^b(G')$ and $s_2 \in G^e(G')$ then there exist a pairwise deviation of (s_1, s_2) such that $s_1 \in G^b, s_2 \in G^b$. In the same way if $s_1 \in G^b(G')$ and $s_3 \in G^e(G')$ then there exist a pairwise deviation of (s_1, s_3) such that $s_1 \in G^b$, $s_3 \in G^b$. So to eliminate similar deviations we consider only stable equilibria with networks of types G^s and G^b.

Suppose $s_1 \in G^b(G')$ and $s_3 \in G^s(G')$ and $N^b(G^b, G') - N^s(G^b, G') \geq 2$, then there exist a pairwise deviation of (s_1, s_3) such that $s_1 \in G^b, s_3 \in G^b$.

Suppose$s_1 \in G^b(G')$ and $s_3 \in G^s(G')$ and $N^b(G^b, G') - N^s(G^b, G') = 1$, then there exist a pairwise deviation of (s_1, s_3) such that $s_1 \in G^e, s_3 \in G^e$ if and only if there exists transfer $t_{3,1}$ such that

$$t_{3,1} \leq z \text{ and } z + t_{3,1} \geq \textstyle\sum_{l,l\neq 2}(t_{l,1} - B_{1,l})$$

$$2z - 1 + \textstyle\sum_{l,l\neq 2}(t_{l,1} - B_{1,l}) \leq 0$$

If seller s_1 has incentives to deviate to (s_1, s_3) then s_2 also has incentives to deviate to (s_2, s_3) because we know that $s_2 \in G^b \in G'$. The transfer that s_2 demands is lower transfer than the transfer that s_1 demands, because he does not need to pay a fixed cost level and he gets access for free. So if $t_{3,2} \geq 1 - z$, there will be a deviation from the equilibrium. We may conclude that under condition $z \geq \frac{1}{2}(1 - z \leq z)$ equilibrium characterized by $s_1 \in G^b(G')$ and $s_3 \in G^s(G')$ and $N^b(G^b, G') - N^s(G^b, G') = 1$ is not stable.

Suppose that $s_1 \in G^b(G')$ and $s_3 \in G^s(G'))$ and $N^b(G^b, G') - N^s(G^b, G') = 1$ and $z \leq \frac{1}{2}$, so in inequality above $2z - 1 \leq 0$ and $\sum_{l,l\neq 2}(t_{l,1} - B_{1,l}) \leq 0$ by definition. Then there is always a deviation from the equilibrium.

Suppose that $s_1 \in G^b(G')$ and $s_3 \in G^s(G')$and $N^b(G^b, G') - N^s(G^b, G') = 1$ and $z \geq \frac{1}{2}$, so in inequality above $2z - 1 \leq 0$ and $\sum_{l,l\neq 2}(t_{l,1} - B_{1,l}) \leq 0$ by definition. Then there is always a deviation from the equilibrium.

So we can say that equilibrium with $N^b(G^b, G') - N^s(G^b, G') = 1$ does not exist.

Given the restrictions above we determine the stable set as a set being externally and internally stable.

Now we suppose that $s_1 \in G^b(G_0)$, $s_2 \in G^e(G_0)$ and $s_3 \in G^s(G_0)$ and network G' is formed as a part of stable equilibrium, such that$s_1 \in G^e(G')$. Sellers of type $G^s(G_0)$ buy access from sellers of type $G^b(G_0)$. Seller of type G^{e} could resell the access from G^b , but they would have no profit. Then there is no pairwise deviation from the equilibrium network G' and transfers $\{t_{i,j}\}_{i,j}$ if there are incentives to breach the contract ($1 - B_{3,1} \leq z + t_{3,1}$ and$t_{3,1} \leq z$). Obviously, there exist a set of transfers like this if and only if $z \geq 1 - z - B_{3,1} z \geq \frac{1}{2}(1 - B_{3,1})$. If number of sellers in the network is equal to the number of buyers, there is no competition for the sharing agreement. If there are more sellers than buyers, then each seller $s_3 \in G^s(G_0)$ transfers exactly $t_{3,1} = 1 - z - B_{3,1}$ to a seller $s_1 \in G^b(G_0)$. ►

Proof of Proposition 5

◀a) Suppose the first statement is not the case and there exists a pair of buyers $b_1 \in N_N \cap B$ and $b_2 \in N_P \cap B$ such that $v(b_1) > v(b_2)$. Assume buyer b_2 serves as the best alternative offer to some seller s_2. Buyer b_1 has no impact on the equilibrium prices, but it is connected to a seller s_1. Then there is always a profitable pairwise deviation of coalition (s_1, s_2), since sharing access to b_1 with s_2 does not affect the bargaining power of any seller besides s_2, and it allows s_2 to increase his payoff by charging a higher price. It proves the first statement.

b) Suppose the second statement is not valid for two buyers $b_1 \in N_P \cap B$ and $b_2 \in N_A \cap B$ such that $v(b_1) > v(b_2)$. Buyer b_2 trades with s_2 and buyer b_1 does not trade with anyone, but provides an alternative offer to seller s_1. Since b_1 does not trade with anyone, seller s_1 gets at least the payoff

$$a.o.(s_1) = v(b_1) - v(s_1),$$

which we call alternative offer. According to the paper of Elliot (2010), the payoff of seller s_1 trading with buyer b_i is a function

$$V_{s_1} = a.o.(s_1) + z(v(b_i) - v(s_1) - a.o.(s_1) - a.o.(b_i))$$

...

After s_1 and s_2 share the access to b_1, seller s_1 may change the alternative buyer, but his minimum payoff will still exceed the payoff that s_1 could get if traded with b_1:

$$a\hat{.}o.(s_1) \geq v(b_2) - v(s_1) - a.o.(b_2).$$

$$\hat{V}_{s_1} = a\hat{.}o.(s_1) + z(v(b_i) - v(s_1) - a\hat{.}o.(s_1) - a.o.(b_i)).$$

Additional surplus to seller s_1 then becomes

$$\hat{V}_{s_1} - V_{s_1} = (1-z)(\hat{a.o.}(s_1) - a.o.(s_1)) = (1-z)(v(b_2) - v(b_1) - a.o.(b_2)).$$

Following the same logic the payoffs of s_2 before and after sharing can be found as

$$V_{s_2} = p(s_2, b_2) - v(s_2)$$

$$\hat{V}_{s_2} = \hat{p}(s_2, b_2) - v(s_2)$$

$$\hat{p}(s_2, b_2) = zp(s_2, b_2) + (1-z)v(b_1),$$

and a corresponding increase in utility is

$$\hat{V}_{s_2} - V_{s_2} = (z-1)p(s_2, b_2) + (1-z)v(b_1) = (1-z)(v(b_1) - p(s_2, b_2))$$

.

Then the total pairwise surplus from the deviation is

$$\hat{V}_{s_2} - V_{s_2} + \hat{V}_{s_1} - V_{s_1} \geq (1-z)(v(b_2) - p(s_2, b_2) - a.o.(b_2)) = (1-z)(V_{b_2} - a.o.(b_2)) \geq 0$$

So there is always a profitable pairwise deviation, which contradicts the fact that equilibrium strategies are stable. We just proved that only buyers with the highest values will trade.

c) Suppose the statement is false, then there exist $s_1 \in N_A$ and $s_2 \in N_P \cup N_N$, such that for trading seller it is more costly to produce a good $v(s_1) > v(s_2)$. We are going to show that it is always pairwise profitable for seller $s_1$to share access to his trading partner and to his alternative buyer. Two sellers will always negotiate on the transfer $t_{1,2}$ if the total pairwise benefit is positive, so we just need to show that there exist bargaining actions that provides a higher utility level than $p_{1,1} - v(s_1)$. It is the case when seller s_2 gets access to all connections of seller s_1 for the transfer $t_{1,2} = p_{2,1} - v(s_1) - \varepsilon$. Seller s_2 bids the same price that $s_1$proposed in the no-sharing setup and gets payoff of $p_{1,1} - v(s_2)$. Playing cooperatively, seller s_1 abstains from any bids and gets payoff of zero. Total pairwise payoff increases by $v(s_1) - v(s_2) > 0$, the payoff of s_2 increases by ε and the payoff of s_1 increases by $v(s_1) - v(s_2) - \varepsilon$. So we proved the existence of a pairwise deviation.▶

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