Employment with connections: Negative network effects*

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Abstract

In less developed countries, it is widely observed that employers hire workers through employee referrals. In this paper, we show an extension of this kind of networks may decrease applicants' payoffs while a diversification of the networks can raise referred applicants' payoffs. We also discuss the effect of the extension of interlinked contracts on farmers' wages.

Keywords: Employee referrals; Lemon effect; Bargaining effect
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1 Introduction

Employee referrals, which are widely observed in less developed countries (LDCs), may be one of the institutions to cope with informational asymmetries. Nakanishi(1991), who investigates the living in a slum in Manila, notes that many workers stated it was impossible to find jobs without any referrals. He concludes that a primary factor in firm's employment strategy is neither an applicant's public education experience nor his skill but "trust", which can only be established by referrals from common acquaintances. [1]

Employee referrals are also related to migration decisions as they influence the probability of finding jobs. Those with more connections with urban residents are more likely to

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[1] Granovetter(1985, 1995) sheds light on the importance of personal contacts in getting a job and clarifies how economic action is embedded in structures of social relations. Granovetter (2005) also points out that prospective employers and employees prefer to learn about one another from personal sources whose information they trust.

leave their villages for the city.[2] In LDCs, whether or not employee referrals are available determines, to a large extent, the migrants' welfare and opportunities.

Montgomery(1991) is a pioneer work incorporating employee referrals into economic theory. He builds a two-period model with two types and shows that as probability that a period-1 worker knows a period-2 worker, which he calls *network density*, increases, (1) the more high type workers at period-2 bypass the market, which decreases the period-2 market wage, (2) the referral wages, wages that period-2 workers with connection receive, increase because it intensifies the competition between offers. In recent years there have been a number of other theoretical papers on search and screening through networks such as Bala and Goyal(2000), Taylor(2000), Fafchamps(2002) and Calvo-Armengol(2004). Wahba and Zenou(2005) empirically find that the probability to find a job through social networks increases and is concave with the size of the network and that the effects are stronger for the uneducated in Egypt using the 1998 Labor Market Survey.

In this paper, we extend Montgomery's model to capture bargaining problems in recruitment through networks. Referrals reveal applicants' information only to the referred firms, which is unavailable to the other firms, generating bargaining problems between the applicant and the referred firm.[3] We find that an increase in the ratio of connected applicants leads to reduction in market wage and referral wages while an increase in the number of connections per connected applicant raises referral wages but does not influence market wage. If the number of connected applicants increases, more high type applicants bypass the market, leading to reduction in the market wage, which curtails applicants' outside options and results in a reduction in referral wages. On the other hand, if a connected applicant has more connections, it improves applicants' outside options and referral wages.

The following section describes the model and in section 3 we argue the extension to the case of interlinked transactions, which are often observed in villages of LDCs. Section 4 offers concluding remarks. For simplicity, we assume the existence of long-term relations between firms and employees so that firms can punish employees effectively if they disguise the referred workers' types, which ensures truthful reporting by employees of applicants.[4]

[2]Carrington et al(1996) model migration boom by incorporating moving costs that decreases as the number of those who already migrated raises, which reflects the increase in connection. Nakanishi(1991) argues that, without any social relations with urban informal sectors, potential migrants will prefer staying in the village.

[3]We assume that applicants can not use public signals to get jobs, following Nakanishi's finding that in low productive informal sectors, a primary factor in employment is not public signals such as education but "trust" established via referrals. While public signals reveal applicants' information, leading to Bertrand competition between firms, referrals reveal their information only to the referred firms, which generates bargaining problems. Thus the focus of our analysis is on unskilled labor markets in LDCs.

[4]Saloner(1985) shows in the equilibrium firms can construct the truthful ranking of employees from the referrals, although his setting is a bit different from ours. Anyway it seems natural to suppose that firms can get finer information by referrals.

2 The Model and the Analysis

Assume that employee referrals reveal applicants' information only to the referred employers as noted above. The referral is a perfect signal and multiple referrals do not add any information. Let the ratio of applicants knowing employees who will refer them to the employees' firms be λ. This can be interpreted to indicate the extent of the connection network, so we call λ *network extent*[5]. We define the increase in λ as *network extension*. Applicants with connections can ask employees to refer them to firms, and otherwise they must find jobs in the market. If they use referrals, they must pay referral costs $C(\geq 0)$, including considerations to employees, future repayment,[6] time costs of the probation period, transaction costs and so on. Firms compete with each other in the Bertrand manner in the market. By hiring an applicant of productivity θ_i, firm's output increases by θ_i.[7] Applicants' productivity θ is continuously distributed on $[\underline{\theta},\ \bar{\theta}\ ]$ independently and identically. In the market, firms do not know applicants' productivity, but know the distribution of θ.[8] So the market equilibrium wage, w^*, is equal to the expected productivity of the applicants participating in the market. Applicants' population is normalized to be 1. Both applicants and firms are risk-neutral.

2.1 An Applicant knows at most one employee

As a first step, we consider the special case where each applicant knows at most one employee. If a firm employs a referred applicant of productivity θ_i, he produces value of θ_i. If it does not hire him, then it instead employs an applicant in the market where competition between firms makes their expected profit zero while he finds a job there and get w^*. Thus an agreement between them produces a surplus of $\theta_i - w^*$. They negotiate the division of this surplus. In this case there are too many Nash equilibria. So we employ the Nash solution as a bargaining solution concept of this game.[9] Nash solution is defined as the solution of

$$\max_{u_i \in U:\ u_i \geq d_i} (u_1 - d_1)(u_2 - d_2).$$

[5]In the real world, who has connections may not be exogenous but be related to one's income for instance. For simplicity, we assume exogeneity of λ.

[6]In reciprocal communities, those who receive favors from other members feel socially obligated to repay the favor. Nakanishi (1990) also finds that reciprocity is one of the important norms in the slums in Philippines. If applicants have their friends refer them to their firms, they would repay the favor in some way. They would also feel obligated to work hard to save their friends' honor, which is the reason employers think that "trust" can be established via referrals.

[7]As we assume constant returns to labor, firms hire any referred applicant i as long as the wage is lower than θ_i. In the equilibrium, all workers who apply obtain a job. Employers all have jobs for all workers.

[8]Note that the firm needs to know the conditional distribution of θ since certain applicants self-select out as described below.

[9]See Osborne and Rubinstein(1990) for Nash solution. Recently, Nash solution has been applied to incomplete contract theory such as Grossman and Hart(1986), which analyze the role of ownership, and to intrahousehold models, which deal with resource allocations among family members such as Quinsumbing and Maluccio(2000).

where u_i is i's payoff ($i = 1, 2$), d_i is i's outside option,[10] and U represents the feasible payoff set. In order to incorporate the bargaining power of each other, we generalize by considering the solution of

$$\max_{u_i \in U:\ u_i \geq d_i} (u_1 - d_1)^{\gamma}(u_2 - d_2)^{1-\gamma},$$

where $\gamma \in [\,0,\ 1\,]$ represents player 1's bargaining power, which may depend on laws or social norms.

If a firm and a referred applicant with productivity θ_i agree on wage w_i^R, then the firm's payoff is $\theta_i - w_i^R$, and the applicant's, w_i^R. The former outside option is zero and the latter w^*. The Nash solution of this problem is

$$w_i^R = (1 - \gamma)\theta_i + \gamma w^*. \tag{1}$$

and the firm takes $\gamma(\theta_i - w^*)$, where γ represents firm's bargaining power.

The outside market equilibrium wage is equal to the expected productivity of the applicants participating in the market. λ of the applicants have referrals. They participate in the market only when they do not use referrals. Applicant i uses referrals if and only if $w_i^R - C > w^*$.[11] Using (1), we get

$$\theta_i > w^* + \frac{C}{1 - \gamma}. \tag{2}$$

We call (2) a referral use condition.[12] Thus the expected productivity of the applicants with connection in the market is expressed as $E[\,\theta \mid \theta \leq w^* + C/(1-\gamma)]$. $(1-\lambda)$ of the applicants have no referrals and all of them participate in the market. The expected productivity of the applicants without connection in the market is $E[\,\theta\,]$. Thus the equilibrium wage is determined by

$$w^* = \frac{\lambda F(w^* + C/(1-\gamma))E[\,\theta \mid \theta \leq w^* + C/(1-\gamma)] + (1-\lambda)E[\,\theta\,]}{\lambda F(w^* + C/(1-\gamma)) + (1-\lambda)} \tag{3}$$

where $F(\cdot)$ is a cumulative density function of the applicants' productivity.

For an explicit analysis, we assume θ is uniformly distributed on $[\,\underline{\theta}, \bar{\theta}\,]$.[13] (3) is expressed as

$$w^* = \frac{1}{2}\frac{(\bar{\theta}^2 - \underline{\theta}^2) - \lambda[\,\bar{\theta}^2 - (w^* + C/(1-\gamma))^2]}{(\bar{\theta} - \underline{\theta}) - \lambda[\,\bar{\theta} - (w^* + C/(1-\gamma))]}. \tag{4}$$

[10] Outside option is the payoff he would get when the negotiation breaks.

[11] We assume if an applicant is indifferent between using referrals and participating in the market, then he or she chooses the latter. This assumption does not affect the result.

[12] If $\bar{\theta} \leq E[\,\theta\,] + \frac{C}{1-\gamma}$, then no one uses referrals. We assume this is not the case.

[13] We derive the condition that the analysis below be satisfied under general density functions in Appendix.

If $\bar{\theta}$ is less than $w^* + C/(1-\gamma)$, no one uses referrals, so we assume

$$\bar{\theta} > w^* + \frac{C}{1-\gamma}. \tag{5}$$

By (4), we derive

$$\frac{dw^*}{d\lambda} = \frac{1}{2}\frac{\left(\frac{C}{1-\gamma}\right)^2 - (\bar{\theta} - w^*)^2}{(\bar{\theta} - \underline{\theta}) - \lambda(\bar{\theta} - w^*)}. \tag{6}$$

The denominator is positive, and the numerator is negative by (5). So we have

$$\frac{dw^*}{d\lambda} < 0. \tag{7}$$

The increase in λ (network extension) reduces the market equilibrium wage. Note that the change in λ also changes the threshold of the referral use condition, so that we also get a shift in the proportion of workers who use referrals. And referred applicant i's wage is $w_i^R = (1-\gamma)\theta_i + \gamma w^*$, thus

$$\frac{dw_i^R}{d\lambda} < 0,$$

which is conditional on the type continuing to use referrals. Network extension decreases referral wages.

In the market with informational asymmetry, the equilibrium wage is uniform for all applicants participating in the market and equal to their expected productivity. But more productive applicants can get higher referral wages and more benefits from bypassing the market. This exodus of productive applicants from the market reduces the expected productivity in the market and cuts off the market wage, inducing further exodus. We define this as the *lemon effect*.[14] [15] The fall in the market wage deteriorates the outside option of referred applicants and undermines their bargaining position, leading to the decrease in their wages. We define this as the *bargaining effect* and the combination of lemon effect and bargaining effect as the *negative network effect*. The information revelation only to the referred firms produces these bargaining problems. In the signaling models, applicants' information is revealed to many firms and Bertrand competition between firms takes place. In this case, applicants' wages are equal to their own productivity and there is no bargaining effect, while the lemon effect still exists.[16]

[14]The source of this term is famous Akerlof's *lemon*. See Akerlof(1970) The term, *lemon effect*, is also used in Montgomery(1991), denoting the decrease in the market equilibrium wage induced by the increase in network density.

[15]If $C = 0$ and $\lambda = 1$, $w^* = E[\theta \mid \theta \leq w^*]$. In this extreme case, all the workers other than the least productive worker will ask for a referral and w^* is equal to the productivity of the worst worker (lemon problem). Note that if $C = 0$ and $\lambda < 1$ or if $C > 0$ and $\lambda = 1$, then some applicants with referrals whose productivity is more than $\underline{\theta}$ also prefer not using the referrals.

[16]In another extreme case where two applicants i and j ($\theta_i < \theta_j$) compete for a job in a Bertrand manner, applicant j would win the job by offering wage $(\theta_j - \theta_i) + w^* + C$. In this case, both the lemon effect and the bargaining effect exist.

Definition 1 *We define the lemon effect as* $\frac{dw^*}{d\lambda}(<0)$*, and the bargaining effect as* $\frac{dw_i^R}{dw^*}(>0)$*. The negative network effect is* $\frac{dw_i}{d\lambda}(<0)$*, where* w_i *denotes applicant* i*'s wage.*

Further in the Appendix we show that when there is a lemon effect,

$$\frac{dw^*}{dC} > 0, \quad \frac{dw^*}{d\gamma} > 0.$$

From (1) and $\frac{dw^*}{dC} > 0$, we get $\frac{dw_i^R}{dC} > 0$, which is also conditional on the type continuing to use referrals as $\frac{dw_i^R}{d\lambda}$. If using referrals becomes more costly, the ratio of applicants bypassing the market by using referrals falls and the expected productivity of applicants in the market increases. The increase in w^*, in turn improves the outside options of referred applicants and raises their wages. For those workers who do not use referrals anymore, however, wages actually fall. The reduction in applicants' bargaining power $(1-\gamma)$ has the same effect on w^*. The market equilibrium wage is higher when applicants' negotiation power is weak than when it is strong. This is because high bargaining power of applicants raises referral wages and induces exodus of productive applicants from the market, which causes the lemon effect. The effect of γ on w_i^R is, however, ambiguous.

In addition, network extension reduces aggregate payoff of the applicants and increases that of the firms. To show this, it is sufficient to consider only the firms' payoff since the total pie of this economy is constant. In the market, their expected profit is zero. On the other hand, they earn positive profit, $\gamma(\theta_i - w^*)$, through negotiation with referred applicant i. By (7), network extension raises their profits. The ratio of referred applicants is $\lambda(1 - F(w^* + C/(1-\gamma)))$, which is increased by network extension (by (7)). Thus firms' aggregate expected payoff increases and applicants' aggregate payoff decreases as λ increases.

We summarize the result above as Proposition:

Proposition 1 *In the case where each applicant knows at most one employee, as long as employee referrals are used,* $\frac{dw^*}{d\lambda} < 0$ *(lemon effect),* $\frac{dw_i^R}{d\lambda} < 0$ *(negative network effect). Network extension decreases aggregate payoff of the applicants.*

The conclusion so far is that network extension deteriorates the market wage as well as referral wages. Our model above, however, is a special case in that even if networks extend, applicants still know at most one employee. In the next subsection, we will relax this assumption.

2.2 Applicant knows many employees

When an applicant knows multiple employees, we must analyze separately the cases of complete information and of incomplete information about the applicants' outside options. In the previous subsection, firms know that the applicant has only one employee who refers him and that his outside option is definitely the payoff from participating in the market. But if an applicant knows more than one employee, his outside options may be the payoff from the market or may be that from the referred firms.

2.2.1 Case 1. Firm knows applicant's outside options

First, assume λ of applicants know two employees: one is employed by firm X, and another, Y. Suppose applicant i is first referred to X. If he disagrees with X, then he makes a choice between using another referral to Y with payment of referral cost C and finding jobs in the market.[17] Therefore in bargaining with X, applicant i's outside option is $w^R_{Y,i} - C$ or w^*, where $w^R_{Y,i}$ is the referral wage that Y offered to i. Note that the firm's outside option is zero as in the previous subsection.

This problem can be solved backward. If $w^R_{Y,i} - C > w^*$, applicant i uses the referral to firm Y after he disagrees with X. In bargaining with firm Y, his outside option is w^* as in the previous section. Thus the Nash solution is the same as (1) and is given by

$$w^R_{Y,i} = (1-\gamma)\theta_i + \gamma w^*. \tag{8}$$

Then consider the bargaining game between firm X and applicant i. Now his outside option is $w^R_{Y,i} - C$. The Nash solution is proved to be $w^R_{X,i} = (1-\gamma)\theta_i + \gamma w^R_{Y,i} - \gamma C$. By substituting $w^R_{Y,i}$ into this, we get

$$w^R_{X,i} \;=\; (1-\gamma^2)\theta_i + \gamma^2 w^* - \gamma C$$

On the other hand, if his outside option is w^*, the case is the same as in the previous subsection: $w^R_{X,i} = (1-\gamma)\theta_i + \gamma w^*$.

He uses the referral to firm Y if and only if $w^R_{Y,i} - C \geq w^*$, or equivalently $(1-\gamma^2)\theta_i + \gamma^2 w^* - \gamma C > (1-\gamma)\theta_i + \gamma w^*$. By using (8), we get

$$\theta_i > w^* + \frac{C}{1-\gamma}.$$

This is the same as the referral use condition (2) when an applicant knows at most one employee.

In addition, by substituting $w^R_{X,i} = (1-\gamma^2)\theta_i + \gamma^2 w^* - \gamma C$ into $w^R_{X,i} - C > w^*$, it is shown that applicant i uses the referral to firm X if and only if

$$\theta_i > w^* + \frac{C}{1-\gamma}.$$

This is also just the same condition as (2).

These imply there is no change in the distribution of productivity in the market. Thus the expected productivity in the market and w^* are irrelevant to the increase in the number

[17] We assume that the applicant will approach the firms sequentially. Indeed, the applicant can pay 2C and have the two employers compete for him in Bertrand fashion. Note that, however, the primary factor in employment is trust established via referrals. If the applicant does not succeed in showing his loyalty to the employer, he would fail in getting a job. Having the two employers compete for him might make them feel that he is not so trustable. In some cases, the applicant has to serve a probation period before getting hired there. Therefore, here we assume that the applicant approach the employers one by one.

of employees they know. The lemon effect is not generated and neither is negative network effect.

The result above can easily be extended to n-employee case. In this case, the wage settled between applicant i and the first referred firm, $w^R_{1,i}$, is

$$w^R_{1,i} = (1-\gamma^n)\theta_i + \gamma^n w^* - (\sum_{m=1}^{n} \gamma^{m-1} - 1)C. \tag{9}$$

The increase in n mitigates bargaining effect because $\frac{dw^R_{1,i}}{dw^*} = \gamma^n$ and $0 \leq \gamma \leq 1$. In addition, the increase in referral costs C decreases referral wages. By differentiating (9) by C, it turns out that as n increases, the effect of referral costs on referred wages becomes larger.

Furthermore, the referral use condition is, derived by $w^R_{1,i} - C \geq w^*$,

$$\theta_i > w^* + \frac{C}{1-\gamma}$$

Again, this is the same as (2). w^* is not affected by the increase in n and lemon effect($\frac{dw^*}{d\lambda}$) is invariant to n.

n can be interpreted as the diversity of networks. Thus we call n *network diversity*, and the increase in n *network diversification*.

When network diversification occurs, the payoff of applicants not using referrals remains unchanged because there is no change in the referral use condition and w^*, as noted above. On the other hand, for applicants using referrals, the change in their payoffs when network diversity increases from $n-1$ to n is

$$\Psi_i(n) - \Psi_i(n-1) = \gamma^{n-1}(1-\gamma)\left(\theta_i - w^* - \frac{C}{1-\gamma}\right). \tag{10}$$

where $\Psi(n)$ is their payoff when they know n employees. It is nonnegative by the referral use condition. Note that there is no increase in payoff for the marginal applicant who is indifferent between using referrals or not, that is, the applicant whose productivity is $w^* + C/(1-\gamma)$[18]. Think again the case of two firms; X and Y. By substituting $\theta_i = w^* + C/(1-\gamma)$ into (8), we obtain $w^R_{Y,i} = w^* + C$. His outside option in negotiating with X would be w^* or $w^R_{Y,i} - C$, which turn to be totally same. In general, for the marginal applicants, the referral wages are always equal to the market wage plus referral cost. This explains why the referral use condition does not change when n increases. Only the applicants whose productivity satisfies the referral use condition can gain a higher payoff by having more referrals. On the other hand, the payoff of applicants without networks and applicants who do not use referrals is w^*, which is invariant to n. Thus the increase in n never decreases any applicants' payoff. The degree of increase becomes smaller as n becomes larger.

[18]This is from the referral use condition (2).

So far we assumed that the network diversity of every applicants with networks was n, however, the referral use condition is independent of n so that w^* is independent of n. Therefore, we can extend our model to general cases where applicant 1 knows n_1 employees, applicant 2 knows n_2 employees, ..., and $1-\lambda$ of applicants have no connection. Thus, the following proposition is established.

Proposition 2 *Suppose applicant i knows n_i employees and $1-\lambda$ of applicants has no connection. Then applicant i's wage is*

$$\begin{aligned} w_i &= w_{1,i}^R = (1-\gamma^{n_i})\theta_i + \gamma^{n_i} w^* - (\sum_{m=1}^{n_i} \gamma^{m-1} - 1)C \quad \text{if} \quad \theta_i \geq w^* + C/(1-\gamma), \\ &= w^* \quad \text{otherwise}. \end{aligned}$$

w_i is a nondecreasing function of n_i(network diversity). w^* is invariant to n_i, given by

$$w^* = \frac{\lambda F(w^* + C/(1-\gamma)) E[\theta |\ \theta \leq w^* + C/(1-\gamma)] + (1-\lambda) E[\theta]}{\lambda F(w^* + C/(1-\gamma) + (1-\lambda)}.$$

The lemon effect ($\frac{dw^*}{d\lambda} < 0$) and negative network effect ($\frac{dw_i}{d\lambda} < 0$) exist, but the latter becomes smaller as n_i becomes larger by mitigating bargaining effect ($\frac{dw_i^R}{dw^*}$). The lemon effect is independent of n_i.

In Montgomery (1991), the increase in network density reduces the market equilibrium wage, w^*, and drives up referral wages. In our model, we classify the development of networks into network extension and network diversification. The former depresses both the market wage and referral wages while the latter increases referral wages but does not affect the market equilibrium wage. The effects are quite different between when the number of an applicant's connections increase from zero to 1 and when from 2 to 3, or from 3 to 4, ...

Furthermore, it is easily shown that

$$\frac{dw_i^R}{dC} = -(\sum_{m=1}^{n_i} \gamma^{m-1} - 1) + \gamma^{n_i} \frac{dw^*}{dC} < \frac{dw^*}{dC}.$$

provided that $\frac{dw^*}{dC} > 0$, which is satisfied if lemon effects exist.[19] As n_i increases, the negative effect of the first term becomes larger and $\frac{dw_i^R}{dC}$ is more likely to be negative. The increase in C discourages relatively productive workers from using referrals and raises w^*. Thus, the increase in C has transfer effect of income from those using referrals to those in the market. Especially, the amount of the transfer from those with more connections is larger. The decrease in applicants' bargaining power $(1-\gamma)$ also has such transfer effect. These equalize income distribution among the applicants while they enlarge inequality between firms and applicants.

[19] See Appendix.

2.2.2 Case2. Firm has no information of applicants' outside options

Our task here is to analyze the case where firms have no information about applicants' outside options. Here we use the generalized Nash solution as the bargaining solution proposed by Harsanyi and Selten(1972). Letting the type of player 1 and 2 be $t_1 \in T_1$ and $t_2 \in T_2$, and the marginal probability of being type t_i be $p^i(t_i)$, the generalized Nash solution can be defined as the solution of

$$\max_{u_i \in U:\ u_i \geq d_i} \left(\prod_{t_1 \in T_1} (u_1(t_1) - d_1)^{p^1(t_1)} \right) \left(\prod_{t_2 \in T_2} (u_2(t_2) - d_2)^{p^2(t_2)} \right).$$

We further incorporate the bargaining power, γ.

Firm k does not know whether applicant i has other referrals. If he has a referral to firm l, his outside option is $w_{l,i}^R - C$, where $w_{l,i}^R$ is referral wage firm l pays to applicant i. If he does not, his outside option is w^*. We can regard whether an applicant has other referrals as his type. We let the probability that applicant i has other referrals be p_i. Suppose each firm is identical. The generalized Nash solution is obtained by

$$\max_{w_{k,i}^R} (\theta_i - w_{k,i}^R)^\gamma [(w_{k,i}^R - (w_{l,i}^R - C))^{p_i} (w_{k,i}^R - w^*)^{1-p_i}]^{1-\gamma},$$

Take the logarithm of the function and we can derive the first order condition,

$$\frac{-\gamma}{\theta - w_{k,i}^R} + \frac{(1-\gamma)p_i}{w_{k,i}^R - w_{l,i}^R + C} + \frac{(1-\gamma)(1-p_i)}{w_{k,i}^R - w^*} = 0. \tag{11}$$

Each firm is identical and thus acts symmetrically in the equilibrium, that is $w_{k,i}^R = w_i^R \ \forall k$. In the previous case of complete information, the outside options of the applicant depend on the order of firms he referred to.

Appendix shows that the generalized Nash solution is

$$\begin{aligned} w_i^R = & \frac{\theta_i + w^*}{2} - \left(\frac{1-p_i}{2p_i} + \frac{\gamma}{2(1-\gamma)p_i} \right) C \\ & + \frac{1}{2(1-\gamma)p_i} \sqrt{(1-\gamma)^2 p_i^2 (\theta_i - w^* - C)^2 + Q} \\ Q = & \ 2p_i(1-\gamma)(1-2\gamma)(\theta_i - w^*)C + (1 - 2p_i + 2\gamma p_i)C^2 \end{aligned} \tag{12}$$

and the bargaining effect is

$$\frac{dw_i^R}{dw^*} = \frac{1}{2} \left(1 - \frac{(1-\gamma)p_i(\theta_i - w^* - C) + (1-2\gamma)C}{\sqrt{(1-\gamma)^2 p_i^2 (\theta_i - w^* - C)^2 + Q}} \right), \tag{13}$$

where $\frac{dw_i^R}{dw^*} > 0$ if $C \neq 0$. Therefore the bargaining effect is also generated in an asymmetric information case. The larger p_i, the probability that i has other referrals, the milder bargaining effect. This corresponds to the increase in n_i (network diversity) in the previous subsection. Therefore, p_i can be interpreted as an indicator of network diversity in imperfect information cases. In addition, the bargaining effect depends on referral costs C. This is different from the case under complete information. If C is large, then the bargaining effect is also large.

The referral use condition is shown to be[20]

$$\theta_i > w^* + \frac{C}{1-\gamma}. \tag{14}$$

This is the very same condition as (2). It is not dependent on p_i, an indicator for network diversity. Thus w^* is also independent of p_i.

Therefore the same conclusion as the previous section is applicable; network extension generates lemon effect and deteriorates the aggregate applicants' welfare through bargaining effect, while network diversification improves it by mitigating bargaining effect. The increase in referral costs and the decrease in applicants' bargaining power raises the market equilibrium wage.

3 Empirical Facts and Extension to Interlinked Transactions

We have argued that network development has two effects on applicants' wages: lemon effect and bargaining effect. Some works on labor markets in developing countries verify the significance of these two effects.

Munshi(2003) investigates job networks among Mexican migrants in the U.S. labor market and finds that an individual is more likely to be employed and to hold a higher paying nonagricultural job when his network is exogenously larger. This supports our results that when an applicant has more connections, he will receive a higher referral wage through the bargaining effect.

Our model can be applied to other situations such as interlinked transactions. Interlinkage is one of the main characteristics of rural transactions in LDCs. For example, landlords lend money to their tenants or wage laborers, and they repay it by working for the landlords at lower wage rates than their marginal productivity. Transactions between traders and farmers provide another example. Traders offer credit for farmers as well as buy their products. Farmers borrowing money from traders sell their products to them at a lower price than the market price.[21]

Since farmers can sell their labor/products at a higher price in the outside market, it is required to establish enduring relationship to prevent farmers from taking such opportunistic actions. In Chambar, Pakistan, lenders do not entertain loan requests from farmers who have not had previous dealings with them (Aleem (1993)). Before they lend money

[20]See Appendix.

[21]On interlinkage, see Basu(1997) and Ray(1998).

to farmers, they make sure that they can trust them. This fact suggests that a screening period is required before they enter interlinked transaction. This process and entailing costs can be interpreted as transaction costs or barrier to entry. If farmers have access to other landlords, they must pay these transaction costs. It is analogous to referral costs C in the case of employee referrals.

In the screening process, landlords select farmers who are productive enough to repay their debts. In this process, farmers' productivity is revealed only to the landlords who transact with them. More productive farmers will get *better conditions* by bargaining with their landlords.[22] On the other hand, the market wage is invariant to farmers' productivity due to information asymmetry. Bardhan and Rudra (1981) survey agricultural labor contracts in West Bengal and report "while there is no uniformity in the wages received by annual-contract laborers in a village, there is a remarkable uniformity in the wage rate received by a daily contract adult laborer". The market for daily contract adult labors corresponds to the market while the market for annual-contract laborers corresponds to referred applicants. Therefore we expect that the market wage rates are lower in the regions where interlinked transactions are more prevailing if there exists a lemon effect.

Indeed, Bardhan and Rudra (1981) find some weak evidence that in villages where interlinked transactions exist, the market wage rate is somewhat depressed. The mean harvesting wage rate per hour of male labor is estimated to be 455g of rice in such villages and 480g in villages where interlinked transaction does not exist, whose difference might be attributable to the lemon effect.

4 Concluding Remarks

Our model describes the situation where there exist (1) informational asymmetry, (2) two tier market which causes adverse selection, and (3) bargaining between agents and principals. Our analysis can be applied to situations where the above conditions are satisfied.

In this paper, we clarify the difference of network extension and network diversification. Network extension causes lemon effect and reduces market wage, which in turn curtails referral wages through bargaining effect. On the other hand, network diversification raises referral wages through bargaining effect while it does not change market wage since it does not incur lemon effect. Montgomery also refers to lemon effect, but does not consider bargaining effect. By distinguishing these two effects, we can have clearer understanding of network effects on workers' wages.

We assume that network extent and network diversity is exogenous. In the reality, however, people try to develop their own networks to get more valuable information and opportunities as some recent theoretical works such as Bala and Goyal(2000) and Calvo-Armengol(2004) discuss. Further research on the network formation of informal workers and its outcome on economic outcome in developing countries is required.

[22]In interlinked contracts, welfare level depends on not only wage rate but also interest rate. This is why we use the expression "better conditions" instead of "higher wages" unlike the employee referral case.

Appendix

On Proposition 1 under general distribution functions

Not that using partial integration and $F(\underline{\theta}) = 0$, we get

$$\begin{aligned} E[\,\theta \mid \theta \le w^* + C/(1-\gamma)] &= \int_{\underline{\theta}}^{w^*+C/(1-\gamma)} \theta \frac{f(\,\theta\,)}{P(\theta \le w^* + C/(1-\gamma))} d\theta \\ &= w^* + \frac{C}{1-\gamma} - \frac{\int_{\underline{\theta}}^{w^*+C/(1-\gamma)} F(\,\theta\,) d\theta}{F(w^* + C(1-\gamma))}. \end{aligned}$$

By Substituting this equation into (3) and rearranging it, we obtain

$$(1-\lambda)(E[\,\theta\,] - w^*) = \lambda \left(\int_{\underline{\theta}}^{w^*+C/(1-\gamma)} F(\,\theta\,) d\theta - \frac{C}{1-\gamma} F(w^* + C/(1-\gamma)) \right). \qquad (15)$$

Differentiation of the both sides produces

$$\begin{aligned} \frac{dw^*}{d\lambda} &= \frac{w^* - E[\,\theta\,] - \int_{\underline{\theta}}^{w^*+C/(1-\gamma)} F(\,\theta\,) d\theta + \frac{C}{1-\gamma} F(w^* + C/(1-\gamma))}{R} \qquad (16) \\ R &= 1 - \lambda[1 - F(w^* + C/(1-\gamma)) + \frac{C}{1-\gamma} f(w^* + C/(1-\gamma))]. \end{aligned}$$

Using $\int_{\underline{\theta}}^{w^*+C/(1-\gamma)} F(\,\theta\,) d\theta = (w^* + C/(1-\gamma))F(w^* + C/(1-\gamma)) - \int_{\underline{\theta}}^{w^*+C/(1-\gamma)} \theta f(\,\theta\,) d\theta$, the equation above can be expressed as

$$\frac{dw^*}{d\lambda} = \frac{w^*[1 - F(w^* + C/(1-\gamma))] - \{E[\,\theta\,] - \int_{\underline{\theta}}^{w^*+C/(1-\gamma)} \theta f(\,\theta\,) d\theta\}}{R}. \qquad (17)$$

Further, by using

$$\begin{aligned} E[\,\theta\,] - \int_{\underline{\theta}}^{w^*+C/(1-\gamma)} \theta f(\,\theta\,) d\theta &= \int_{\underline{\theta}}^{\bar{\theta}} \theta f(\,\theta\,) d\theta - \int_{\underline{\theta}}^{w^*+C/(1-\gamma)} \theta f(\,\theta\,) d\theta \\ &= \int_{w^*+C/(1-\gamma)}^{\bar{\theta}} \theta f(\,\theta\,) d\theta \\ &= E[\,\theta \mid \theta \ge w^* + C/(1-\gamma)\,] \cdot [1 - F(w^* + C/(1-\gamma))], \end{aligned}$$

we get the following expression.

$$\frac{dw^*}{d\lambda} = \frac{\{w^* - E[\,\theta \mid \theta \ge w^* + C/(1-\gamma)\,]\}[1 - F(w^* + C/(1-\gamma))]}{R}. \qquad (18)$$

$E[\,\theta \mid \theta \ge w^* + C/(1-\gamma)\,]$ is the expected value of θ on the condition that θ is greater than $w^* + C/(1-\gamma)$, so it must be greater than w^*. Since $0 \le F(w^* + C/(1-\gamma)) \le 1$, the numerator of (18) is nonpositive regardless of C.

Thus a necessary and sufficient condition for Proposition 1 to hold is that R is positive. Especially, it is sufficient for $F(w^* + C/(1-\gamma)) - \frac{C}{1-\gamma} f(w^* + C/(1-\gamma))$ to be nonnegative. This condition is expressed in figure 1. If C is small, this condition is necessarily satisfied.

By (15), we also get following results;

$$\frac{dw^*}{dC} = \frac{\frac{C}{(1-\gamma)^2} f(w^* + C/(1-\gamma)}{R}, \tag{19}$$

$$\frac{dw^*}{d\gamma} = \frac{\frac{C^2}{(1-\gamma)^3} f(w^* + C/(1-\gamma)}{R}. \tag{20}$$

The denominators of both (19) and (20) are positive, so if R is positive, or $\frac{dw^*}{d\lambda} < 0$ (lemon effect), then $\frac{dw^*}{dC} > 0$ and $\frac{dw^*}{d\gamma} > 0$

Derivation of the solution and its properties in Case 2

Substitute $w^R_{j,i} = w^R_{k,i} = w^R_i$ into (11), then we get

$$\begin{aligned}(1-\gamma)p w_i^{R\ 2} - [(1-\gamma)p(\theta_i + w^*) - (1-p+\gamma p)C]w_i^R \\ +[(1-\gamma)p\theta_i w^* - \gamma C w^* - (1-\gamma-p+\gamma p)\theta_i C] = 0\end{aligned} \tag{21}$$

By using the solution formula of quadratic equation, we finally derive

$$\begin{aligned} w_i^R = {} & \frac{\theta_i + w^*}{2} - \left(\frac{1-p}{2p} + \frac{\gamma}{2(1-\gamma)p}\right) C \\ & + \frac{1}{2(1-\gamma)p}\sqrt{(1-\gamma)^2 p^2 (\theta_i - w^* - C)^2 + Q}, \\ Q = {} & 2p(1-\gamma)(1-2\gamma)(\theta_i - w^*)C + (1-2p+2\gamma p)C^2. \end{aligned} \tag{22}$$

By differentiating above by w^*, bargaining effect is derived as

$$\frac{dw_i^R}{dw^*} = \frac{1}{2}\left(1 - \frac{(1-\gamma)p(\theta_i - w^* - C) + (1-2\gamma)C}{\sqrt{(1-\gamma)^2 p^2(\theta_i - w^* - C)^2 + Q}}\right). \tag{23}$$

If $\frac{(1-\gamma)p(\theta_i - w^* - C) + (1-2\gamma)C}{\sqrt{(1-\gamma)^2 p^2(\theta_i - w^* - C)^2 + Q}}$ is less than 1, then bargaining effect is positive. For proving this, it is sufficient to show that

$$[(1-\gamma)p(\theta_i - w^* - C) + (1-2\gamma)C]^2 < (1-\gamma)^2 p^2 (\theta_i - w^* - C)^2 + Q. \tag{24}$$

By rearranging this, we get the condition that

$$\gamma(1-\gamma)(1-p)C > 0. \tag{25}$$

Thus unless γ and/or p are equal to 1, bargaining effect exists. The greater the difference between the both sides of (24), the stronger bargaining effect is. By (25), it is clear that as C increases, bargaining effect exerts a greater influence on the referral wages.

Applicant i uses the referral if $w_i^R - C > w^*$. We substitute (12) into this and finally get

$$\sqrt{(1-\gamma)^2 p^2 (\theta_i - w^* - C)^2 + Q} > [(1-\gamma)(1+p) + \gamma]C - (\theta_i - w^*)(1-\gamma)p. \qquad (26)$$

For deriving the referral use condition, we focus on the applicant who is indifferent between using the referral and using the market, so let $\hat{\theta}$ be such an applicant's productivity. By squaring the both sides of (26) and rearranging it, we finally get

$$\hat{\theta} = w^* + \frac{C}{1-\gamma}. \qquad (27)$$

The difference between the both sides of (26) becomes larger as θ_i increases, thus θ_i s.t. $\theta_i > \hat{\theta}$ always suffices (26). Therefore, the referral use condition is

$$\theta_1 > w^* + \frac{C}{1-\gamma}. \qquad (28)$$

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