Ties that Bind: Network Redistributive Pressure and Economic Decisions in Village Economies

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Selected Paper prepared for presentation at the 2016 Agricultural & Applied Economics Association

Annual Meeting, Boston, Massachusetts, July 31-August 2

Abstract

In this paper, we identify the economic implications of the pressure to share resources within a social network. Through a set of field experiments in rural Tanzania we randomly increased the expected harvest of a treatment group by the assignment of an improved and much more productive variety of maize. We find that individuals in this group reduced their interaction with their own network. We also find that treated individuals reduced labor input by asking fewer network members to work on their farm during the growing season and, as a result, obtained fewer harvest gains.

Keywords: Ego-network, Field Experiment, Redistributive pressure, Harvest, Tanzania

JEL: O12, O13, C93, H26, Z13

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1 Introduction

Social networks – a key component of social capital – play an important role for the livelihood and development prospects of communities in the developing world.[1] They provide informal insurance and credit when markets are imperfect or absent (e.g. Udry, 1990; Rosenzweig, 1988; Fafchamps, 1992; Greif 1993, Coate and Ravallion, 1993; Townsend, 1994, Udry, 1994, Anderson and Baland, 2002, Ligon et al. 2002, Fafchamps and Lund, 2003, Barr et al. 2012; Kinnan and Townsend, 2012), facilitate technology diffusion (Bandiera and Rasul, 2006; Conley and Udry, 2010) and provide opportunities for human capital investment and resource redistribution (Angelucci and De Giorgi, 2009; Angelucci et al., 2010).[2] The quintessential characteristic of social network relations is the obligation that is experienced by its members.[3] The more successful members of the network must help the least successful members of the social network (Rosenzweig and Wolpin, 1994). They may also be requested to contribute more to local public goods (Olken and Singhal, 2011). Resource redistribution within the network can, therefore, be characterized like a sort of 'informal' redistributive tax (Platteau, 2000; Baland et al., 2011; Squires, 2015). And like a tax it may trigger an *evasive* response. This view is supported by recent experimental evidence (Jakiela and Ozier, 2016, Beekman et al. 2015; Boltz et al.;

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[1] See Durlauf and Fafchamps (2005) and Jackson (2006) for a review.

[2] Households' expectations of future assistance and transfers are key motivators behind participation in these networks. Other explanations such as altruism, guilt and potential social sanctions also seem to play an important role in shaping individual interactions in networks (Platteau 2000, Foster and Rosenzweig 2001, Barr and Stein 2008, Leider et al., 2009, Alger and Weibull 2010, Ligon and Schechter, 2012).

[3] In this respect, Scott (1976) and Platteau (1991) refer to the 'moral economy'.

2015).[4] An underexplored research question is to what extent this evasive response may correspond to ill-suited economic decisions. For instance, would individuals reduce economically profitable social interactions so as to prevent resource sharing with network members? In this paper we aim to fill this gap by exploring the economic implications of a social network's redistributive pressure.

We designed a set of field experiments in rural Tanzania that exploited the differential productivity of maize seeds. We randomly assigned to a treatment group a more productive, improved variety of maize. The control group received and planted instead a traditional, lower yielding variety. With yields that are up to five times larger than the traditional ones, improved maize substantially raises the expected future harvest and income of those receiving it. We tested if these subjects altered some dimensions of their interaction with their neighbors in the social network.[5] In rural Tanzania, like in many parts of the developing world, farming is usually a 'family' business. All members of a given household are involved in different farming activities (e.g., soil preparation, sowing, weeding, fertilizer application, harvesting, threshing) providing the amount of labor required in the production process. Social networks, however, are an effective way of expanding labor. A typical example of this are the labor sharing agreements within the social network under which a household head invites members of other households to support these specific practices and activities. Using one's network, labor input in production processes is

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[4] In the context of an experimental study of involuntary giving, similar findings have emerged. Dana et al. (2006), for instance, found that 28% of senders in a standard dictator game preferred to hide at a cost rather than to send nothing to the receivers.

[5] An alternative would have been to provide farmers with an unconditional cash transfer. Cash is, however, more easy to conceal than seeds. This would have made the detection of potential evasive behavior more difficult. Moreover, hiding from the network comes with a cost (e.g., having less help in the farm). Our design allows us to capture both of these aspects.

thus increased. The compensation in labor sharing agreements is typically a share of the output, in this case a share of the maize yield (Krishnan and Sciubba, 2009).

We find that the individuals in the treatment group, as compared to the control group, interact less with their *ego-network*[6] (or *neighborhood*) from the moment they receive the seeds and make fewer labor sharing agreements afterwards.[7] We also find that the differences between the control and treatment group increases with the size of the *ego-network*. We do not, however, find a similar pattern for other types of social interactions that do not imply visibility of one's seeds or crops (e.g. asking for information on general agricultural issues).

We find that the size of the ego-network affects the quantity of maize harvested in the treatment group. More specifically, while the improved seed does increase yields, this beneficial effect declines as the number of network members rise. This effect of the increasing ego-network size is not found for the control group with the traditional maize variety.

Our empirical results are guided and supported by a theoretical model. There is a literature, stemming from seminal work of Bramoullé and Kranton (2007) and Bloch et al. (2008), analyzing network formation games based on informal insurance. We analyze this issue in the context of Network Games (e.g., Galeotti et al., 2010; Feri

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[6] By ego-network we refer to what is typically called *neighbourhood* in the theoretical literature on social networks (see e.g. Newman, 2003, Jackson, 2008, and Borgatti et al., 2008, for an overview over the terminology in different disciplines). So, the ego-network of agent i is the set of his direct network members, which is a subset of the overall members of the social network. We prefer not to call this set neighbourhood, because in this context these are mostly members of the extended family or kinship. We therefore use the terms ego-network and kin network interchangeably. We also refer to network members as neighbors and kin interchangeably.

[7] It should be stressed that the improved seeds do not require less labor. Hence the reduced interaction is not a result of a lower labor requirement. This issue is further addressed later on in the paper.

and Pin, 2016).[8] In this context, agents do not know if their direct neighbors are able to directly communicate with each other. This possibility of neighbors communicating increases the number of closed triangles that there are in the social network: a property that is typically referred to as clustering. The literature has mostly analyzed the support of clustering for sustaining cooperation in the context of repeated interaction, e.g. in Kandori (1992), Ellison (1994), Vega-Redondo (2006), Jackson et al. (2012) and Dall'Asta et al. (2012). This paper, however, uses clustering as the measure that summarizes the trade-off between having the possibility to enter into labor sharing agreements with many people and avoiding the leakage of information on their own wealth. In this way, a standard expected utility framework, adapted to the theory of social networks, provides a suitable conceptual environment.

A novel exercise,[9] besides its contribution to the theoretical literature on social networks, our results contribute to two other broad strands of literature. The first is the small but expanding literature linking social networks to input misallocation (Banerjee and Munshi, 2004; Baland et al. 2015; Squires, 2015; Munshi and Rosenzweig, 2016). Unlike the existing literature, however, this paper uses both a theoretical network analysis and a field experiment to test the (theoretical) results. The second strand of related literature is on social pressure and involuntary giving (List and Lucking-Reiley, 2002; Dana et al. 2006; Landry et al., 2006; Dellavigna et al., 2012; Jakiela and Ozier, 2016). This paper confirms some of the key findings in this area (e.g., social pressure increases giving) by providing field evidence on social

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[8] In these papers, agents are embedded in a social network and have to take decisions for which there is strategic interaction with the decisions taken by the agents connected to them. In doing so, however, they have limited observability of the structure of the social network beyond their direct acquaintances, and this framework is analyzed with Bayesian optimization.

[9] To our knowledge the only notable exception is Lamberson (2015) which considers clustering in a network game. The context is however very different from ours.

network redistributive pressure in the developing world.

The paper proceeds as follows. The next section provides a description of the data and the design of the field experiment. We then present the theoretical model and discuss the empirical results. We then offer some final remarks.

2 Design of the experiment

We conducted a set of field experiments in fifteen villages located in two maize growing areas of rural Tanzania, the South-East (Morogoro) and the North (Karatu). These villages may be thought as fairly isolated, self-contained, units as they are often far from each other. Approximately 10 per cent of farmers in each village, a total of 314 farmers, took part in the experiments.[10] Working with a relatively small fraction of farmers per village is necessary to prevent the experimental activity becoming too disruptive of village life. It also reduces the likelihood of general equilibrium effects such as changes in local labor and maize markets.[11] People living in these areas are self-subsistence farmers with crops mostly consumed within the household and any surplus marketed.

Bags containing 1 Kg improved seeds were randomly allocated to about half of the treatment group. The control group received instead, bags containing 1 Kg of the traditional seed variety. The improved variety is named Situka-M1 and was released in 2001 by the Selian Agricultural Research Institute (SARI) in Tanzania. It has a high yield potential of 3-5 ton/ha and its optimal production altitude ranges 1000-1500 masl. The traditional variety instead has a yield potential of 0.5-1 ton/ha under

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[10] When we designed the experiment we did a standard power calculation. Considering a significance level alpha of 0.05, 80 per cent power, an effect of half a standard deviation, and an estimated intra-cluster correlation of 0.036, we obtained a needed estimated sample size of 161.

[11] Providing a large part of the village with improved seeds would have increased substantially the aggregate maize production that would have eventually been traded on the local market.

similar conditions.[12] This relatively small quantity of seeds is sufficient for one plot of land of half a hectare. In these villages, households have on average three plots of half a hectare each. These are often scattered across space and are, on average, 25 minutes walking distance from the homestead.[13] Farmers planted the received seeds on one of their plots and we refer to this as their *experimental* plot.

The field experiment was composed of the following stages. In January 2013, a baseline survey was undertaken. The baseline recorded the total size of the social network including the extended family that each household had (mapping of the ego-network links). Shortly after, the seeds were discreetly distributed to the farmers in closed packages. Once that the package was open it would be easy for the farmer to distinguish if the variety of maize was traditional or improved.[14] The identity of the farmers who received the seeds was not revealed to the rest of the village. Farmers that were not part of the experiment were not informed about our specific research activities.

In February 2013, at the beginning of the rainy season, farmers started planting the seeds on their experimental plots. Between February 2013 and July 2013 a number of interactions by phone and in person between the enumerators and the sample took place. A total of seven field visits ensured that only the seeds that were provided to

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[12] This improved variety is grown in the areas of the experiment and is the second most important open pollinated variety (OPV) in the country. About 12% of farmers in the areas of the research used Situka-M1 during the 2010/11. The variety is tolerant to both drought and pests (e.g., maize streak and grey leaf spot diseases).

[13] Plots allocated to cereals are usually the most distant from the homestead. Vegetables and livestock are held closer.

[14] The seeds of the improved variety are treated with a fungicide to minimize seed loss during storage. This fungicide confers the seeds a purple color. Traditional varieties are never treated with fungicide and have instead a natural pale color. The improved seeds have also more regular and round shape. The growing crop and maize of the improved variety is also visibly different to the traditional variety.

the participants were grown in the experimental plot,[15] check the growing conditions and to collect more agronomic information on soil and agricultural practices.[16] Harvest from the experimental plot took place between July 2013 and August 2013. An end-line survey was also conducted.

Table 1 describes the salient demographic characteristics of the people participating in the experiment. Approximately half of the sample (47%) randomly received the improved seeds. The average network size of a household (e.g. degree) is 9.2 members within the village (with a minimum of 0 and a maximum of 33) and 5.7 members located in other villages. The average household size is 4.95 (with a minimum of 1 and a maximum of 10) with the average head of the household 44 years old, of which 60% had some education. Some of the household heads in the sample are also village leaders (17%). Only 11% of the farm households' heads are female. The average farm size is 1.4 ha and 23% of households own an ox.

[Table 1 – About here]

The balance check for the predetermined variables - the standard test for randomization - is reported in Table A2 in appendix A. It shows that there is no evidence of systematic differences between the treatment and the control group.

As self-subsistence farmers, farming is central to the lives of the sample households and a large part of social interactions relate to agriculture. Most information sharing pertains to crops, harvest, access to inputs and markets and land issues. Our key outcome variables are therefore the social interactions among network members. We,

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[15] A critical issue of this type of field experiments is the possibility of contamination with other type of seeds.

[16] The enumerators measured the experimental plot, recorded intercropping, mulching, the distance between plants, whether weeding took place, and if fertilizer was used.

first focus on a general type of interaction, recording with how many network members in the village the participant discussed the seeds with after they received them. This indicates the very first impact on social interaction that the potential positive shock may have. The second key outcome variable is, consistent with the theory developed below, the number of ego-network members that are asked to work on the farm of participating farmers. These labor-sharing arrangements that expand the labor input in the production process, potentially increase final harvest size. This social interaction could be affected by the size of the ego-network; a larger ego-network allows one to ask for more help from other (perhaps more productive) individuals. Therefore, assuming a constant marginal cost of asking for help, a larger ego-network could induce more social interactions. On the other hand, asking network members to enter into labor sharing agreements entails both visibility and sharing of the harvest.

A farmer with improved seeds has, therefore, to weigh up the benefits and costs of asking for help. We can envisage a direct positive effect and two costs, a direct one and an indirect one. The positive effect is the potential increase in productivity through the increase in labor input. The direct cost is the sharing of the harvest to those who helped. The indirect cost is that, through labor sharing agreements, farmers will reveal their seeds, exposing themselves to the socially imposed *redistributive tax* as a result of potentially increased yields. Farmers in the treatment group face a clear trade-off between the marginal increase in labor productivity and the increase in these direct and indirect costs.

It should be stressed that the improved variety does not require fewer labor inputs than the traditional one. Evidence from agronomic research (and our own evidence from the Table A2) suggests that in fact, the opposite effect may take place.[17] In order to fully exploit the productive advantage of the improved variety *more* labor to undertake agricultural practices should be employed (e.g., in soil preparation, ploughing and weeding). We tested if treatment and control groups are statistically different in these agricultural practices to rule out the hypothesis that improved seeds require less labor. We report the results in the Table A1 in appendix A.

3 A model of network redistributive pressure

Suppose that there are N self-subsistence farmers as nodes in an exogenous undirected social network. As assumed in an emerging literature on *network games*, they have incomplete information on the network: they know only their own degree and the *clustering coefficient* of the network.[18] We measure the clustering coefficient as the i.i.d. probability c that two nodes that have a network member in the village in common are also linked together (again, refer to Newman, 2003, and Jackson, 2008, for a few alternative definitions of the same concept). We assume that there is a single good that can be produced using either the old and less productive technology or the new and much more productive technology. We assume that each agent needs at least one unit of this good to survive. There are three steps at different times.

Time 0: A single agent, denoted by i, is picked at random. Agent i has ℓ network members, i.e. ℓ is the number of individuals in the ego-network of agent i or agents with which he is interacting (sometime in the following we denote ℓ as the *degree* of agent i). Agent i receives the new production technology. The quantity of the good

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[17] Typically, all improved varieties developed require complementary inputs and practices, as well as controlled soil and moisture conditions to reach maximum yields (e.g., Mann, 1978; Byerlee and Polanco, 1986; Doss, 2006).

[18] As will be clear in the following, the coefficient c can be interpreted as the probability that one farmer i's neighbour communicates the relevant information to another farmer i's neighbour

produced by this technology depends on the number of people working on it, denoted by k. Formally, the technology is $f(k)$, where $k \in \{0,1,\dots,\ell\}$.[19] We assume $f(0) > 1$ and that $f(k)$ is no decreasing and concave, i.e. $\Delta f(k) = f(k) - f(k-1) \geq 0 \ \forall\, k \in \{1 \dots, \ell\}$ and $\Delta^2 f(k) = \Delta f(k) - \Delta f(k-1) \leq 0 \ \forall\, k \in \{2 \dots, \ell\}$.

Every other agent in the social network, who is not i, uses the old technology that provides a quantity of 1 with probability $1 - p$, and 0 with probability p, where these probabilities are *i.i.d* across agents.

Time 1: At the beginning of the period agent i chooses, among his ℓ neighbors, k agents that he can employ in his technology. Agent i makes a take–it–or–leave–it offer to each of the chosen k network members. This offer is a form of insurance where agent i commits him to pay 1 in the case that the realized income of the employed agent is 0. It is straightforward to see that it is dominant for each of them to accept this offer. Any offer less than 1, however, they would not accept as they would risk not surviving.

Time 2: Some agents with bad luck have still a chance to survive: they must be members of the network of both agent i and of one of the agents employed by i. Agent i will have to use all his excess profit to sustain them, up to the point that he is also back to 1.

Finally we assume that: (i) the technology used by agent i is observed only by people working on his farm; (ii) people working for agent i can inform their neighbors that agent i has a new production technology and therefore a possible higher income; (iii)

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[19] $k = 0$ means that only agent i works on the new technology.

people not working for agent i cannot observe the labor sharing arrangements of other agents; (iv) agents are risk neutral and they have linear preferences over the good.[20]

This model is just an optimization problem for agent i that has to choose k in order to maximize her expected payoff. Formally the problem of agent i is:

$$\max_{k\in\{0,1,\ldots\ell\}} f(k) - k\cdot p - g(k,\ell) \qquad (1)$$

where $g(k,\ell) = p(\ell - k)(1-(1-c)^k)$ is the expected *network tax*[21] and $1-(1-c)^k$ is the probability that some agent j, out of the other $\ell - k$ agents, is linked to some of the k agents. We have that:

$$\Delta g(k,\ell) = g(k,\ell) - g(k-1,\ell) = p\big((1-c)^{k-1}\big(1+c(\ell-k)\big)-1\big) \qquad (2)$$

whose sign is not determined, but $\Delta^2 g(k,\ell) = \Delta g(k,\ell) - \Delta g(k-1,\ell) = -p(1-c)^{k-2}c\big(2+c(\ell-k)\big) < 0$, meaning that $\Delta g(k,\ell)$, the marginal expected redistributive tax, is decreasing in k[22] and, consequently, that the expected redistributive tax $g(k,\ell)$ is concave with respect to k. This implies that optimization problem in (1) may not have a unique optimal k. Then by k_ℓ^+ we denote the greater *argmax* of (1), for a given value of ℓ.[23] Furthermore it is directly verifiable that in absence of the redistributive tax the problem (1) becomes simply:

$$\max_{k\in\{0,1,\ldots\ell\}} f(k) - k\cdot p \ ,$$

and has an unique solution denoted by k_ℓ^*.

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[20] We do not need any assumption about replacement of agents who do not survive, because we focus on a “one-shot” situation. Moreover, by this assumption we model the agent’s incentives to work for others.

[21] In this formulation we have simplified, assuming that agent i can face a negative payoff, when the redistributive tax is large. However, since $f(0) > 1$ is always a possibility, this is without loss of generality.

[22] Indeed increasing k reduces the number of agents that can be potentially linked to the k agents.

[23] The problem in (1) may have more local optimal k because $g(k,l)$ is not concave with respect to k.

Proposition 1 is our main result, with its derivation, based on three lemmas, and its technical details are presented in Appendix B. We stress here that it is a very general and to our knowledge, an original result.

Proposition 1 *Suppose that* $\Delta f(1) > p$, *and that there exists* k' *such that for all* $k > k'$, $\Delta f(k) < p(1-c)^{k-1}$, *then there exist* ℓ' *and* $\ell'' \geq \ell' \geq 1$ *such that:*

- *for any* $\ell \leq \ell'$, $k_\ell^+ = \ell$;
- *for* $\ell > \ell''$, *we have* $k_\ell^+ = 0$.
- *for* $\ell' < \ell \leq \ell''$, $0 < k_\ell^+ < \ell$ *and it is not increasing in* ℓ.

So, up to a certain degree ℓ', we have that $k_\ell^+ = \ell$, then k_ℓ^+ decreases and it becomes null at ℓ''. Figure 1 provides an intuition for the result, even if the figure is based on the case where both ℓ and the solution to the problem in equation (1) are continuous.

[Figure 1 – About here]

Note also that the introduction of the redistributive tax causes a distortion in the optimal number k_ℓ^+ of employed workers. That is because the marginal redistributive tax $\Delta g(k,\ell)$ can be positive or negative, and so the distortion on the labor sharing decision can be in the direction of either employing more or less neighbors, with respect to k_ℓ^*. Then, an interesting question is how does the redistributive tax bias the production with respect to what would be optimal without this informal taxation?

The answer to this question is not straightforward because the effect of the redistributive tax on the individual optimization problem is not monotone. Without redistributive tax, agent i may hire either fewer members of the network (neighbors), to reduce the leakage of information about her increased output, or more neighbors to reduce the number of those that are not employed. There is, however, also the constraint imposed to agent i with a small ego-network, as she cannot hire more people than are known. This tradeoff is solved by the following corollary (where ℓ' *and* ℓ'' *are those from Proposition 1).* As a benchmark we use k_ℓ^*, defined above, which is the solution of problem (1) without the family tax.

Corollary 2 *Suppose that* $k_\ell^* \geq 1$ *and that there exists* k' *such that for all* $k > k'$, $\Delta f(k) < p(1-c)^{k-1}$*then there exists an integers* $\bar{\ell}$ *with* $\ell'' \geq \bar{\ell} \geq \ell'$ *such that:*

- *for any* ℓ *such that* $\bar{\ell} \geq \ell$, $k_\ell^+ \geq k_\ell^*$ *;*
- *otherwise* $k_\ell^+ < k_\ell^*$ *.*

So, for an intermediate range of degree ℓ the redistributive tax produces a bias in the hiring decision in the direction of more neighbors employed with respect to the benchmark. Outside this range, agent i asks for help to fewer neighbors with respect to the benchmark case, with $\ell \geq \ell''$ being the degenerate case of no neighbors used at all. Figure 1 provides an intuitive explanation for the result, based on the continuous approximation.

Note that the assumption $\Delta f(1) > p$ is eliminating the case where the solution of the problem is equal to 0 for all ℓ.[24]

The second condition on the production, namely that $\Delta f(k) < p(1-c)^{k-1}$ for any $k > k'$, only states that in some point the marginal revenues have to become smaller than marginal costs. This is a plausible assumption for all production processes characterized by congestion problems, when there is even a value of k such that an additional unit of k causes a reduction in the production level (so, the assumption is consistent with negative marginal revenues). This assumption is eliminating the case

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[24] Indeed if $\Delta f(1) < p$ the solution of the problem when $\ell = 1$ is $k = 0$: this has to be the solution for all problems with $\ell > 1$ (as comes out from the Lemmas discussed in Appendix B). This case happens when the marginal revenues are too small to profitably hire someone. This case is not of our interest because the same solution is applied when there is no tax.

where the solution of the problem is always equal to ℓ for any size of the ego-network, which happens when the marginal revenues are so high that hiring everyone is always the best solution.[25]

Finally, one implicit assumption of the model is that only one agent within a given network receives the new production technology. A natural question is to ask, therefore, is what happens if more agents receive the new production technology? In this case individuals do not know who has received the new technology. They do know, however, that their neighbors and their neighbor's neighbors could be endowed with the new technology. In such a case we can have the following effects.

1. With some probability the individual entering into a labor sharing agreement with the agent will also be endowed with the new technology, thus the expected payment from the labor sharing arrangement will be lower as the individual has sufficient yield of their own to not need additional yield.
2. With some probability the individual entering into a labor sharing agreement with the agent will have another connection endowed with the new technology, thus the expected payment from the labor sharing agreement will be lower as there are multiple sources from which the individual may request support.
3. With the probability that more than one individual has received the technology the redistributive tax on an agent will be lower because there are greater yields in the network overall.
4. With a higher probability that the individual entering into a labor sharing agreement with an agent either works or has worked with other people endowed

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[25] Note that this solution is applied to the case of no redistributive tax only when $\Delta f(k) \geq p$ for all k. But in the presence of tax the solution to hire everyone can happen even if $\Delta f(k) < p$, because the marginal costs for k sufficiently close to ℓ are negative.

with the new technology, the expected marginal revenue is increased through knowledge transfer.

Our model can take into account all these effects by simply changing the parameter values. The effects in points 1, 2 and 3 are reducing parameter p. The effect in point 4 could induce higher marginal revenues. So we can reasonably assume that if we remove the assumption that only a single agent receives the new production technology, the main results are unchanged.

4 Data analysis and results

This section relates our theoretical results to our empirical understanding of how social network interactions are affected by increases in the expected harvest. Taking proposition 1 and corollary 2 to the data, we start by considering the social interactions that increase the risk of revealing the type of seeds received in the experiment: discussing the type of seeds received in the experiment or asking for help on the farm. The estimation tests whether farmers, having received improved seeds, change the nature of their social interactions with their network, focusing on interactions that are more likely to make the others aware of their higher expected income.

4.1 Empirical strategy

We begin by testing if individuals in the treatment group reduce interaction within the network by simply telling a smaller number of their peers about the seeds they received. We start therefore by a simple regression where the dependent variable D_i is the number of network members with whom farmer i has discussed the type of seeds received and the independent variable S_i is a dummy that takes value 1 if farmer i has received the improved seed, otherwise is equal 0:

$$D_i = \beta_0 + \beta_s S_i + e_i \quad (3)$$

where e_i is the farmer i's error term. We then add to the list of regressors the network size in the village and its interaction with the treatment (receiving improved seeds).[26] We thus, estimate the following:

$$D_i = \beta_0 + \beta_s S_i + \beta_N N_i + \beta_I N_i \cdot S_i + e_i \quad (4)$$

where N_i is the network size that farmer $i$has in his village and $N_i \cdot S_i$ is the interaction effect between the improved seeds dummy and the network size. We are particularly interested in the estimated coefficients β_s and β_I. We then consider the effect of the same explanatory variables on the number of network members to which farmer i has asked for help on the farm in a labor sharing agreement. We also add a large set of controls. These include individual and farm characteristics such as age of the household head, household size, female headed household (dummy), education (dummy), risk aversion of the household head, land size, oxen (dummy), labor, walking distance to the plot (in minutes), access to credit proxied by participation in rotating saving schemes, and burial societies. We control for important environmental and climatic conditions that may affect harvest: we include dummies for pest damage and for region and we capture differences in the climatic conditions including *The Standardized Precipitation Index* (SPI- ARC2 dataset).[27] We also control for

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[26] It may be argued that the error term might be correlated with the social network variable. Nizalova and Murtazashvili (2014) have shown both analytically and with simulations that the OLS estimate of the interaction term in this context is still consistent if one condition holds. The condition is that the (presumably) endogenous variable and the unobserved heterogeneity are jointly independent from the exogenous treatment. This is fulfilled thanks to the randomization of the allocation of the improved seed.

[27] This index captures the rarity of a drought at a given time scale of interest for any rainfall station with historic data. It can also be used to determine periods of anomalously wet events. Being a standardized measure, it identifies normal conditions when close to zero. High SPI value corresponds to heavy precipitation event over time period specified while low SPI signal situations of low

reciprocity by including a variable that captures the number of passive interactions, i.e. if the household head has been asked to help on the farm of other network members during the last 6 months. This is potentially an important variable as subjects may already be in labor sharing agreements. They therefore ask for help with farming only because they have been asked previously.

Lowering labor inputs will have implications in terms of harvest. By asking for less help, farmers with improved seeds do not reap the full potential of the improved seeds. We therefore investigate if there are explicit economic implications - through lower output - as a result of the interplay between changing expected harvest and network size (corollary 2). Specifically, we test whether the positive effect of improved seeds is sensitive to the size of the network as a result of evasive behavior (Bandiera and Rasul, 2006). In order to test for this, we estimate a model similar to equation (4) except that the dependent variable is harvest instead of the social interactions.

We further support our results by undertaking a set of checks. We are particularly interested in probing the mechanism of evasive behavior in response to the increase in the expected harvest. We therefore estimate if similar pattern would be found in case of other types social interactions that do not directly involve discussing the new seeds or their visibility. In order to test for this, the left-hand side variable of equation (3) and (4) is replaced with either the number of people asked for asked about information on land markets, or about best farming practices.

In order to limit the effect of having many zeroes in the dependent variable, i.e. people who have not asked for help, we use a Poisson and a zero-inflated Poisson

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precipitation event. The lower the SPI the more dramatic is the drought. We used the GIS information to locate the farmers and then matched this information with rainfall data to produce the SPI.

model alongside standard OLS regressions. All regression results are presented with standard error robust to clustering at the village level and corrected for small cluster size (Cameron, Gelbach and Miller, 2007).

4.2 Empirical results

Table 1 reports the summary statistics of the variables used in the analysis. The average number of network members asked to enter into a labor sharing agreement during the last 12 months is 1.9 while the standard deviation is 2.8 with a maximum of 20. The average for the group with improved seeds is 1.7 while the average for the control group is 2.1.

Table 2 reports the results. Column (1) reports a baseline specification without controls. We find that compared to the control group, individuals assigned the improved seeds reduced their network interactions from the moment they received the seeds. They revealed to fewer in their ego-network that they received the improved seed (significant at 10%).

[Tab 2- About - here]

How does the size of the network in the village affect this result? Column (2) in Table 2 presents the results of the extended model including the effect of ego-network size. We find that the effect of improved seeds on the number of members with whom the seed type was revealed is sensitive to the size of the network. The coefficient estimated for this interaction term is negative and statistically significant. For field experiment participants in the control group, the larger the kin network the larger the number of discussions about the type of seeds: one additional member in the network size increases the number of discussions by 0.15 (significant at 5%). This is expected as a larger number of kin increases the number of opportunities to discuss and reveal that some seeds were received. Different patterns apply for the participants in the treatment group. For any given ego-network size, farmers with improved seeds revealed the type of seeds they received to a smaller number of farmers. This difference increases with network size and becomes significant for farmers with a kin network larger than 11 people, i.e. a network size just larger than the average. This highlights that individuals with the increased expected harvest reduced social interaction and is coherent with the idea that the pressure to share, and the corresponding evasive behavior, increases with ego-network size. To probe the robustness of our results we add a large battery of controls. Results are reported on column (3) of Table 2 and are consistent after the inclusion of the control variables.

We also expect farmers to reduce those interactions that would make their seeds and potential harvest more visible, such as entering into labor sharing agreements. Let us consider a situation in which a farmer normally asks some members of her ego-network to come on her operating plots and help with land preparation, seeding, harvesting etc. If she has the improved seeds and she does not want to share harvest with all of them (i.e., she does not want to be taxed), she may ask only a smaller number of more trusted members. Perhaps, those individuals are less likely to diffuse the information about their expected harvest with the rest of the network. Table 3 presents the results of the analysis. Column (1) shows that, on average, farmers with improved seeds asked 0.35 less people for help on the farm (significant at the 10% confidence level). Furthermore, column (2) shows that farmers with traditional seeds ask more people for help on the farm when their ego-network is large while this is not the case for farmers with improved seeds. For the latter, an increase of one kin increases the number of people asked to come for help on the farm by 0.02 (not statistically significant). The difference between the seed groups becomes significant for farmers counting 12 or more people in their kin network, i.e. a network size larger than the average, and the difference increases as the size of the kin network increases. The results are again robust and consistent after the inclusion of all the controls.

[Table 3 – About here]

We now investigate the economic implications of such different behavior. We test for this by comparing harvest between farmers with improved and traditional seeds at various ego-network sizes. Results are presented in table 4.

[Table 4 – About here]

On average, improved seeds increase expected harvest by 60% as shown in column (1). Furthermore, the size of ego-network for farmers with traditional seeds increases the harvest by 4% for each additional member. This is coherent with the idea that the ego-network provides some important services (e.g., information and resources) that increase an individual's harvest when growing traditional varieties of maize. A different pattern emerges, however, for the treatment group. The average effect of ego-network size is not statistically different from zero. It suggests that the evasive behavior, via reducing labor input, may have an economic cost. For farmers with a large ego-network (20 members, i.e. 15% of the sample), the evasive behavior completely cancels out the benefit of the improved seeds. These results are summarized in Figure 2.

[Figure 2– About here]

We also tested if social interactions that do not require the type of seed to be revealed differed between farmers in the treatment and control group. This constitutes an important test to see if evasive behavior would take place in social interactions that do not increase the risk of a redistributive tax. We investigated four types of social interactions implying no direct visibility, as the interaction does not take place on the farm of the participants on the experiment. These include general discussions on output markets, on land markets, and on best farming practices. Table (5) shows the results.

[Table 5 – About here]

As expected, we do not find any sign of evasive behavior. Farmers with improved seeds do not differ from farmers with traditional seeds in the number of social interactions with no seed visibility. Furthermore, the effect of ego-network size does not differ between control and treatment groups as shown by the lack of significance of the interaction term. Results suggest that evasive behavior does not take place in social interactions that do not increase the risk of incurring a redistributive family tax.

Lastly, in order to take into account the count data nature of the dependent variables and the large number of zeroes, we implemented a Poisson and Zero-inflated Poisson model. Results are shown in table 6. Results are found to be comparable to the ones obtained with simple OLS. They are also illustrated in Figure 3.

[Table 6 – about here]

[Figure 3 – about here]

5 Concluding remarks

In this paper we presented both theoretical and empirical evidence of the economic implications of social networks in the developing world. We frame the issue with a model where network clustering has an effect on an individual's decisions. The model predicts that individuals wanting to reduce redistributive pressure from other network members may reduce their social interactions. This includes a reduction in social interaction that could have provided gain through increased output. We tested the model via a field experiment that relied on the random assignment of improved seeds that greatly increase the expected maize harvest. We find that farmers receiving improved seeds interact less with their social ego-network. The treated group not only are less likely to discuss with other farmers their seeds, but also entered in fewer labor sharing agreements than in the control group. This indicates that evasive responses may be made to avoid network-sharing pressures. Farmers that receive positive income shocks prefer to reduce their visibility by reducing involvement with their ego-network rather than facing the risk of higher redistributive tax.

These findings echo the work of Baland et al. (2011) where farmers in Cameroon were ready to incur a cost to avoid being taxed by their ego-network. In the case presented in this article, the cost is the forgone marginal productivity of labor on a plot with improved seeds. Hence, both studies highlight another mechanism by which the *dark side* of social capital can compromise wellbeing: the inefficiency is not only due to *disincentivized* farmers free-riding on the solidarity of their peers, but to a suboptimal level of labor due to the fear of being taxed.

Although it is difficult to draw any conclusion on the long term welfare equilibrium dynamics due to the cross-sectional nature of the present study, this implicit cost can be interpreted as the *deadweight loss* of the informal insurance system embedded in social networks. It is a *deadweight loss* because the additional food that could have been produced by marginally increasing labor will simply never exist. The members of the solidarity network will have fewer resources to share.

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Table 1. Summary Statistics

	Mean	Standard Dev	Min	Max
Number of people with whom the type of seeds were discussed	2.85	2.35	0.00	10.00
Number of people the farmer asked for help on the farm (labor sharing agreements)	1.9	2.76	0.00	20
Harvest (kg)	82.20	72.48	0.00	280.00
Number of people asked about output markets	0.84	1.31	0.00	5.00
Number of people asked about best farming practices	0.89	1.12	0.00	5.00
Number of people asked about information on land markets	0.88	1.34	0.00	5.00
Positive harvest shock (1= improved variety; 0=traditional)	0.47	0.50	0.00	1.00
Network size inside the village (number of relatives and kin)	10.5	10.97	0.00	72
Network size outside the village number of relatives and kin)	7.16	9.99	0.00	73
Age of household head	44.07	10.08	16.00	70.00
Household size	4.95	2.00	1.00	10.00
Leadership role in the community (1= Yes; 0=otherwise))	0.17	0.37	0.00	1.00
Female headed household (1= Yes; 0=otherwise))	0.11	0.32	0.00	1.00
Secondary education (1= Yes; 0=otherwise))	0.60	0.49	0.00	1.0
Risk averse (1= Yes; 0=otherwise))	22%	0.41	0.00	1.00
Farm size (ha)	1.41	0.92	0.00	4.05
Oxen (1= Yes; 0=otherwise))	23%			
Labor (man day)	8.25	4.83	0.00	22.00
Pest damage (1= Yes; 0=otherwise))	23%	0.42	0.00	1.00
Standardized Precipitation Index	0.22	0.66	-1.27	0.91
Location South -East (1= Yes; 0=otherwise))	41%			

Table 2: Number of network members with whom you discussed the seeds received

	(1) Baseline	(2) With no controls	(3) With controls
Positive harvest shock	-0.66*	0.74	0.43
	(0.37)	(0.83)	(0.67)
Network size		0.15**	0.13**
		(0.06)	(0.05)
Positive harvest shock*Network size		-0.13*	-0.12**
		(0.07)	(0.06)
N:	314	313	313

Village clustered and corrected for small cluster size standard errors in parenthesis.
Significance code: * p < 0.10, ** p < 0.05, *** p < 0.01.
Controls: age of the household head, household size, female headed household (dummy), education (dummy), risk aversion of the household head, land size, oxen (dummy), labor, walking distance to the plot (in minutes), been asked for help in the farm by network members during last 6 months, HH member is the village leader, pest damage (dummy), Standardized Precipitation Index (SPI - ARC2 dataset), dummy for region. Constants not reported.

Table 3: Number of network members labor sharing agreements made with

	(1) Baseline	(2) With no controls	(3) With controls
Positive harvest shock	-0.35^{*}	0.14	0.12
	(0.21)	(0.26)	(0.22)
Network size		0.06^{***}	0.042^{**}
		(0.02)	(0.03)
Positive harvest shock*Network size		-0.04^{***}	-0.028^{**}
		(0.02)	(0.01)
Observations	311	311	311
Adjusted R^2	0.01	0.05	0.07

Village clustered and corrected for small cluster size standard errors in parenthesis.
Significance code: * p < 0.10, ** p < 0.05, *** p < 0.01.
Controls: age of the household head, household size, female headed household (dummy), education (dummy), risk aversion of the household head, land size, oxen (dummy), labor, walking distance to the plot (in minutes), been asked for help in the farm by network members during last 6 months, HH member is the village leader, pest damage (dummy), Standardized Precipitation Index (SPI - ARC2 dataset), dummy for region. Constants not reported.

Table 4: Dependent Variable: Harvest (in logs)

	(1) Baseline	(2) With no controls	(3) With controls
Positive harvest shock	0.58^{***}	0.97^{***}	0.84^{***}
	(0.16)	(0.25)	(0.26)
Network size		0.04^{***}	0.04^{***}
		(0.01)	(0.01)
Positive harvest shock*Network size		-0.03^{***}	-0.03^{**}
		(0.01)	(0.01)
Observations	309	308	301

Village clustered and corrected for small cluster size standard errors in parenthesis.
Significance code: * p < 0.10, ** p < 0.05, *** p < 0.01.
Controls: age of the household head, household size, female headed household (dummy), education (dummy), risk aversion of the household head, land size, oxen (dummy), labor, walking distance to the plot (in minutes), been asked for help in the farm by network members during last 6 months, HH member is the village leader, pest damage (dummy), Standardized Precipitation Index (SPI - ARC2 dataset), dummy for region. Constants not reported.