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Neighborhood effects and social behavior: The case of irrigated and rainfed farmers in Bohol, the Philippines

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ABSTRACT

Artifactual field experiments, spatial econometrics, and household surveys are combined in a single study to investigate the neighborhood effects of social behaviors. The dictator and public goods games are conducted among rice farmers in irrigated and non-irrigated areas in the Philippines. We find the neighborhood effects but the magnitude and statistical significance of endogenous social effects vary with the irrigation availability, type of social behavior, and type of neighborhood. Altruistic and cooperative behaviors are significantly influenced by the behaviors of neighbors only in the irrigated area, where social ties are strengthened through collective irrigation management. Through this effect, irrigated farmers' social behaviors become similar to those of one another. Neighborhood effects for cooperative behavior are stronger among farm plot neighbors than among residential neighbors, which may reflect their interactions in irrigation management. Although non-dynamic, these findings are consistent with the theory of social norm evolution through common pool resource management.

1. Introduction

A growing number of studies have documented the existence of many types of social behavior, such as altruism, trust, and cooperation and punishment for public purposes, contrary to the predictions of the standard *Homo economicus* model (Bowles and Gintis, 2011; Fehr and Gächter, 2000; Henrich et al., 2001; Ostrom, 2000). Moreover, many empirical and experimental studies have observed variation in patterns of social behavior across different groups of subjects (Cardenas and Carpenter, 2008; Gächter et al., 2012; Henrich et al., 2010; Lamba and Mace, 2011). Understanding the determinants of social behavior is important because recent investigations insist that social behavior considerably affects key economic phenomena, including economic growth, poverty reduction, risk sharing, and collective action. Existing studies have focused on macro-level factors, such as market integration, ecology, and culture, as well as micro-level factors, such as group size and

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socioeconomic heterogeneity (Baland and Platteau, 1996; Gächter et al., 2012; Henrich et al., 2010; Ostrom, 2000; Rustagi et al., 2010).

Beyond the examination of the effects of these variables, interest in neighborhood effects has begun to grow. Anselin (2003) addresses the significance of neighbors' influence on economic decision making. Through neighborhood interactions, individuals (or households) affect each other's personal decisions, preferences, information sets, and behavioral outcomes directly rather than indirectly through markets. Hence, the decisions of neighboring individuals are likely to be interdependent. In the context of social behaviors, this type of neighborhood influence may be interpreted as the effect of social norms or community mechanisms.

Over the past decade, the development of spatial econometric techniques has made possible the statistical examination of the interdependent behaviors of individuals who share spatial, social, and economic milieus (Anselin and Griffith, 1988; Anselin, 2003, 2010). In addition, a recent theoretical development in the social network literature provides us with a strategy to solve the identification problem of endogenous and exogenous neighborhood effects that Manski (1993) noted in his landmark study (Bramoullé et al., 2009). Many studies have begun applying the spatial econometric techniques to understand interdependent economic activities such as technology adoption (Case, 1992; Bandiera and Rasul, 2006; Conley and Udry, 2010), economic growth (Pede et al., 2014; Abreu et al., 2005), recreational consumption (Bramoullé et al., 2009), and institutional choice (Kelejian et al., 2013), but, to the authors' knowledge, no attempts have been made to examine social behaviors.

Our research strategy combines artifactual field experiments, spatial econometrics, and household surveys within a single study. Two experiments, a dictator game and a public goods game, are conducted to quantify the altruistic and cooperative behaviors, respectively, of farmers in Bohol, the Philippines. In the context of rural agrarian communities, day-to-day social interactions take place within these communities. Subsequently, the existence of neighborhood effects in social behaviors in these local communities is tested utilizing spatial econometrics controlling for socioeconomic and agro-ecological factors, which are collected through household surveys.

Particular attention is paid to the difference in the degree of neighborhood effects between irrigated and non-irrigated (rainfed) areas. The collective management of common pool resources is considered an opportunity to strengthen ties and generate social norms among local people (Aoki, 2001; Fujiie et al., 2005; Hayami and Godo, 2005; Hayami, 2009; Ostrom, 2000). A gravity irrigation system, which must be managed collectively by users in geographical proximity, was newly introduced into a traditionally rainfed rice area within our study area two years before our survey. This change is expected to strengthen location-based ties and increase similarity in social behavior among geographical neighbors, which can be captured in neighborhood effects utilizing spatial economics (Nakano et al., 2015). This paper intends to show empirically how the increased importance of collective action among local people in the real world enhances interdependence in their general social behaviors (altruistic and cooperative behaviors) among geographical neighbors.

A key finding of the empirical analyses is that neighborhood effects on social behaviors are observed, but the degree of interdependence varies with the irrigation availability, type of social behavior, and type of neighborhood. Variations are summarized in two aspects. First, altruistic and cooperative behaviors are significantly influenced by the behaviors of neighbors only in irrigated areas, resulting in increased similarities in social behaviors in the irrigated area. Note that this finding implies that outcomes may not necessarily be pro-social because the neighborhood effect can reduce the level of high contributors' contributions to their neighbors' level. Vicious cycles in conformism norm dissemination are possible. Second, neighborhood effects for cooperative behavior are stronger among farm plot neighbors than residential neighbors, which may reflect their interactions in irrigation management in the real world. These findings are consistent with the theory of norm evolution through common pool resource management (Aoki, 2001; Hayami and Godo, 2005; Ioannides and Topa, 2010; Ostrom, 2000). The relevance of this interpretation is further strengthened by our supplementary finding; a dissatisfaction message (a type of costly punishment from group members) increases the subsequent contribution during the next round of the public goods game more effectively in irrigated areas. This supports the emergence of a stronger norm enforcement mechanism in the irrigated areas.

Our study contributes to several streams of literature. First, it joins a growing body of literature on social networks. Existing studies discuss the roles of networks in risk sharing (Fafchamps and Lund, 2003; Bramoullé and Kranton, 2007), agricultural marketing (Fafchamps and Minten, 2002), capital mobilization (Banerjee and Munshi, 2000; Fafchamps, 2000), acquisition of employment opportunities (Kajisa, 2007), and peer effects on economic behaviors (e.g., technology adoption, consumption, schooling, and microfinance take-up) (Case, 1992; Bandiera and Rasul, 2006; Conley and Udry, 2010; Kremer and Levy, 2008; Yamauchi, 2007; Bramoullé et al., 2009; Banerjee et al., 2012). We situate our paper within the literature on peer effects and emphasize that we examine such effects in social behaviors with field data.[1] Another unique contribution is that we used geographical neighbors to examine the effects of location-based ties. An advantage of this framework is that our estimation suffered little from the self-selection problem of network structure, which social neighbor factors (e.g., friendship) are likely to have. A disadvantage is that our analysis cannot contribute much to the literature on network formation and the differential performances of formed networks, as our neighbors are set according to distance and, thus, are practically given.[2]

[1] Gächter et al. (2013) detected peer effects in social behavior in an experimental setting, rather than field data.

[2] See Alatas et al. (2012), Jackson (2008), and Bramoullé and Kranton (2007) for recent progress.

Second, our paper adds to the body of literature that found the effects of social ties in the real world on social behavior in their experiments (Binzel and Fehr, 2013; Etang et al., 2011; Goette et al., 2012). Our paper is consistent with these predecessors in that the farmers' experience of collective irrigation management is associated with the interdependence of general social behaviors in the experiment.

Third, our possible contributions to the literature on social norms are twofold. Our results imply not only the development of social norms through collective resource management but also the possibility of vicious cycles. Many experiments in existing studies establish a situation in which the examinees' current behavior fails to meet the level expected by a social norm, and thus, the experiment induces norm-based pro-social behaviors (Ferraro et al., 2011; Goldstein et al., 2008). However, the adverse effect could be possible in the real world. Because both cases were observed in our field data, our study provides a more comprehensive view of the effect of social norms.

2. Background of the study site and survey

Our study site is located in the northeastern part of Bohol, an island in the Central Visayas region belonging to the *Cebuano*-speaking culture of the Philippines. The Bayongan irrigation system located in the study area began operation in 2008. It is a typical gravity irrigation system consisting of a reservoir dam, canals, water intakes, and farm ditches. In principle, water from an intake is shared by a group of farmers. The farmers are mandated to form a water-user group (WUG) that collectively manages the construction and maintenance of farm ditches, the control of water intake, water allocation among the members, and coordination with other WUGs. The system consists of 150 WUGs ranging in size from 4 to 70 farmers, with an average of 20 farmers.

The International Rice Research Institute (IRRI) surveyed 239 randomly selected rice farmers over four agricultural seasons from 2009 to 2011. The artifactual field experiment was conducted in September 2011. These surveys provide the primary individual-level dataset for our study. The surveys include both irrigated and rainfed areas with sample sizes of 132 and 107 farmers, respectively. Because few rainfed farmers exist in the irrigated area, the former sample consists only of irrigated farmers, while naturally the latter contains only rainfed farmers. To facilitate meaningful comparison of the two agroecosystems, we take advantage of the fact that the rainfed area within our study site, as well as the irrigated area, was included in the feasibility study conducted by the National Irrigation Administration and deemed just as hydrologically irrigable as today's irrigated area, but it has not received irrigation services yet because of unexpected fund shortage, while financial support for construction is still forthcoming. In other words, we sampled the rainfed farmers who were supposed to be irrigated. The irrigated and rainfed areas are adjacent. The soil type (sandy loam) is the same in both areas, and the sampled farmers share common background characteristics such as ethnicity (*Cebuano*), religion (Roman Catholic), value systems established in lowland ecology as well as other socioeconomic characteristics, which are examined statistically in Sections 5 and 6.[3]

The dataset consists of household characteristics, the results of the artifactual field experiments, and geographical coordinates. Geographical coordinates are recorded for both the farm plots and the residences of the sampled farmers, which allows us to define two types of neighborhoods (plot and residential) for each farmer.[4] Figs. 1 and 2 present the locations of the residences and farm plots, respectively.

3. Neighborhood effects and hypotheses

Ioannides and Topa (2010) identified three sources of neighborhood effects. First, the direct effects of neighbors' outcomes on an individual's outcome are known as *endogenous social effects*. The propensity of an individual to behave in some way varies with the prevalence of that behavior in some reference group containing that individual. For instance, individuals care about their neighbors' altruism, which then affects their own altruism.[5] That is, one's own decisions and the decisions of others in the same neighborhood are, in some sense, mutually reinforcing. Second, individuals care about the personal characteristics of others, e.g., whether their neighbors are young or old, male or female, rich or poor, black or white, and trendy or traditional. Such effects are known as *exogenous social effects*. Third, individuals in the same social settings may act similarly because they share common unobservable factors or face similar institutional environments. Such an interaction pattern produces *correlated social effects*. A precursor to this concept is found in Manski (1993), who emphasized the difficulty

[3] For network analysis, one may be concerned that the networks based on sample data may not represent the population networks. A simulation result by Santos and Barrett (2008) indicates that random sample data perform fairly well when ties between individuals are constructed randomly. In our context, a pair of people becoming geographical neighbors is not completely random but seems to be much less influenced by individual characteristics than the formation of social networks such as friendship or transaction-based relationships (see our discussion on self-selection issue in Section 3). Admittedly our network data are not as perfect as those based on census data, but we still believe they fairly represent the geographical network structure of our study area.

[4] For farmers with multiple plots, the coordinates of the plot claimed to be most important by the respondents are utilized.

[5] *Endogenous social effects* appear when one cares about the *expected* outcome of the other's decision even without observing the other's actual behavior. For example, a common rate of monetary contribution to ceremonies (such as weddings and funerals) is implicitly set among the people. The co-variation of social behavior observed in our case provides another example.

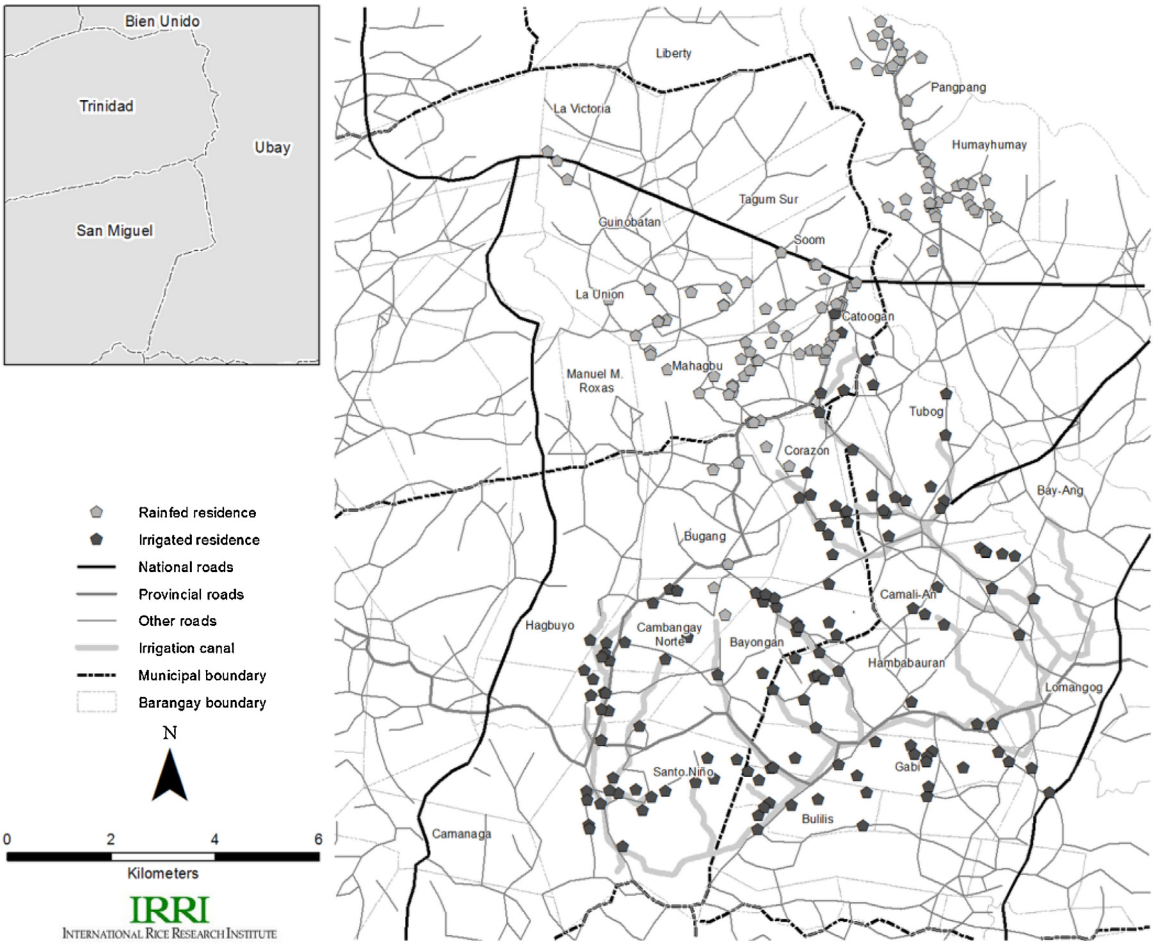

Fig. 1. Map of the survey site in Bohol indicating the locations of the sampled farmers' residences.

in identifying endogenous and exogenous effects separately in linear models as well as in separating these two effects out from the correlated effects. This issue is referred to as the *reflection problem*.

Bramoullé et al. (2009) provided a generalized approach for the identification of social effects by considering an extended version of the linear-in-means model, where interactions are structured through a social network. Their remarkable contribution is their "easy-to-check" test for necessary and sufficient conditions for the identification of (endogenous and exogenous) social effects. We introduce this test and perform it on each of our neighborhood structures to determine whether (endogenous and exogenous) social effects are identified.

Conditional on passing the identification test, we attempt explicit demarcation of the three sources of social effects in our econometric model while referring to these social effects as "neighborhood effects", as the network is based on geographical proximity.

Note that the identification of neighborhood effects may suffer from a self-selection problem (Goette et al., 2012; Manski, 1993). That is, interdependence among individual decisions and behavior within a spatial or social milieu can be complicated by the fact that individuals may choose their own neighborhoods. In other words, individuals may choose their neighborhood effects by selecting their residence or workplace or both. Such choices involve information that is unobservable to the researcher and thus requires inference about possible factors that contribute to their choices (Bandiera and Rasul, 2006; Blume et al., 2011; Brock and Durlauf, 2001; Moffitt, 2001). In our analysis, however, the self-selection problem is assumed to be negligible because we confirmed in interviews that the farmers had not relocated or chosen their community due to the introduction of the irrigation system. Sampson et al. (1999) support this point by indicating that the most reliable conditions in favor of neighborhood effects include residential stability and low population density.

The discussion above drives us to our main empirical questions of whether, under which conditions, and in what ways farmers' social behaviors are influenced by their neighbors' behaviors and characteristics. The study site also indicates that social interactions take place in the rainfed areas as well. Therefore, our first research hypothesis is that

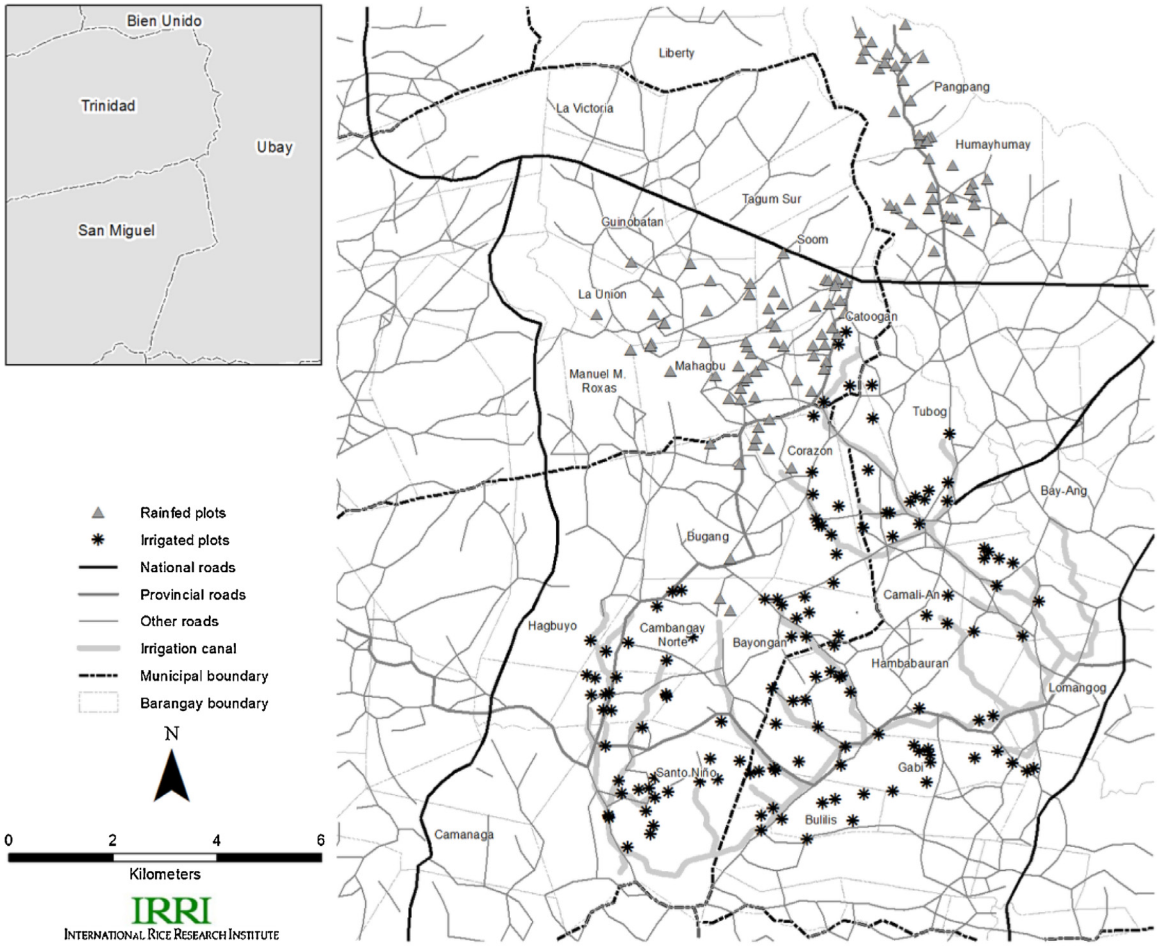

Fig. 2. Map of the survey site in Bohol indicating the locations of the sampled farmers' plots.

H1. The social behaviors of individual farmers are influenced by their neighbors' social behaviors and personal attributes.

Second, social interdependencies are strengthened when individuals share a common pool resource and social space that generate constraints on individual actions (Aoki, 2001; Hayami and Godo, 2005; Ioannides and Topa, 2010; Ostrom, 2000). Because the introduction of irrigation systems increases the demand for collective management of communal water resources among geographical neighbors (Aoki, 2001; Fujiie et al., 2005; Hayami, 2009; Ostrom, 2000), our second hypothesis is that

H2. Neighborhood effects on social behavior, particularly on contributions to public goods, are greater in irrigated areas than in rainfed areas.

Third, neighborhood effects on the contribution of public goods may be greater when we consider farm field neighbors rather than residential neighbors because more intensive collective action is required in the fields than in residential life. Sampson et al. (2002) also emphasize the need to examine social interactions at schools and workplaces in addition to the common practice of searching for neighborhood effects in the place of residence. Accordingly, our third hypothesis is that

H3. The endogenous social effects on the contribution of public goods are more salient among farm plot neighbors than among residential neighbors.

4. Spatial econometric model

4.1. Weight matrix

To represent a neighborhood structure of N sampled farmers, an $N \times N$ weight matrix $\boldsymbol{W}$ is constructed on certain criteria. Because this paper focuses on geographical proximity rather than a social relation-based network, the weight matrix construction is based on the arc distance between observations (spatial units) computed from geographical coordinates.

First, we create a binary matrix with elements coded 1 when two observations (spatial units) are defined as neighbors and 0 otherwise. By definition, the diagonal elements of the matrix, which describe the self-relationship, are all zeroes. The binary matrix is row-standardized so that the row sum is unity. To test the third hypothesis, two types of neighborhood structure are considered, residential neighborhood, $\boldsymbol{W_r}$, and farm plot neighborhood, $\boldsymbol{W_p}$, which allows us to investigate which type of neighborhood has a greater influence on farmers' social behavior.

In our main model, the threshold distance criterion is adopted to construct the neighborhood structure. That is, for a given farmer, all other farmers located within the threshold distance radius are considered his or her neighbors. Because setting a long threshold implies a model in which far-off people are regarded as influential neighbors, which leads to disqualifying the model, our strategy is to employ a threshold short enough to define neighbors who are significant to a given individual. The shortest possible threshold distance maintains that all observations (spatial units) have at least one neighbor (see Section 6 for more details). Later, weight matrices constructed by other criteria are examined to check for robustness in Section 8.[6]

4.2. Spatial regression

The econometric estimation procedure begins with a general model in which a farmer's social behavior depends only on his/her socioeconomic characteristics:

$$\boldsymbol{Y} = \boldsymbol{X}\alpha_1 + \varepsilon_1 \tag{1}$$

where $\boldsymbol{Y}$ represents an $N \times 1$ series of measurements of social behavior (altruistic or contributory behavior) for the individual farmers, $\boldsymbol{X}$ represents an $N \times K$ matrix containing vectors of K variables that measure individual agricultural and socioeconomic characteristics, and ε_1 represents the residual or error term.

The exogenous social effects discussed in Section 3 are systematically modeled by Autant-Bernard and LeSage (2011), utilizing a spatial econometrics framework. Eq. (1) can be modified algebraically as follows to include the influence of neighbors' characteristics:

$$\boldsymbol{Y} = \boldsymbol{X}\alpha_2 + \boldsymbol{W_s X}\beta_2 + \varepsilon_2 \tag{2}$$

where $\boldsymbol{W_s}$ ($s = r, p$) is an $N \times N$ weight matrix, and $\boldsymbol{W_s X}$ is an $N \times K$ matrix containing vectors of the neighbors' weighted averages for the K variables. This specification is also called a cross-regressive model.

Spatial diagnostic tests are then performed on the residual ε_2 to determine the appropriate spatial process (see Anselin et al., 1996). Performing a set of Lagrange multiplier tests and following the procedure outlined in Anselin et al. (1996), potential specifications include (a) a spatial lag model (with spatially lagged independent variables), (b) a spatial error model (with spatially lagged independent variables), (c) a combination of the previous two models (ARAR model with spatially lagged independent variables), and (d) a cross-regressive model (i.e., Eq. (2)). Specifications (a)–(c) are expressed as follows:

$$\text{(a)}\quad \boldsymbol{Y} = \rho_3 \boldsymbol{W_s Y} + \boldsymbol{X}\alpha_3 + \boldsymbol{W_s X}\beta_3 + \varepsilon_3 \tag{3}$$

$$\text{(b)}\quad \boldsymbol{Y} = \boldsymbol{X}\alpha_4 + \boldsymbol{W_s X}\beta_4 + \varepsilon_4, \quad \varepsilon_4 = \lambda_4 \boldsymbol{W_s}\varepsilon_4 + \mu_4 \tag{4}$$

$$\text{(c)}\quad \boldsymbol{Y} = \rho_5 \boldsymbol{W_s Y} + \boldsymbol{X}\alpha_5 + \boldsymbol{W_s X}\beta_5 + \varepsilon_5, \quad \varepsilon_5 = \lambda_5 \boldsymbol{W_s}\varepsilon_5 + \mu_5 \tag{5}$$

where the coefficients ρ, β, and λ capture the endogenous social effects, exogenous social effects, and correlated social effects, respectively. The coefficient ρ indicates the degree of interdependence in social behavior among neighbors. The error terms in Eqs. (4) and (5) are modeled to capture linear correlated social effects in cases where similar behavior among neighbors occurs because unobserved determinants of behavior are correlated across the defined neighbors to each individual. In this respect, the spatial error component is included to absorb and separate out such correlated effects, which contributes to the identification of exogenous and endogenous neighborhood effects.

Eqs. (3)–(5) are transformed into reduced form equations as follows:

$$\text{(a)}\quad \boldsymbol{Y} = (I - \rho_3 \boldsymbol{W_s})^{-1}(\boldsymbol{X}\alpha_3 + \boldsymbol{W_s X}\beta_3) + (I - \rho_3 \boldsymbol{W_s})^{-1}\varepsilon_3 \tag{6}$$

$$\text{(b)}\quad \boldsymbol{Y} = \boldsymbol{X}\alpha_4 + \boldsymbol{W_s X}\beta_4 + (I - \lambda_4 \boldsymbol{W_s})^{-1}\mu_4 \tag{7}$$

$$\text{(c)}\quad \boldsymbol{Y} = (I - \rho_5 \boldsymbol{W_s})^{-1}(\boldsymbol{X}\alpha_5 + \boldsymbol{W_s X}\beta_5) + (I - \rho_5 \boldsymbol{W_s})^{-1}(I - \lambda_5 \boldsymbol{W_s})^{-1}\mu_5 \tag{8}$$

In light of the nonlinearity in coefficients, these spatial models (a)–(c) are popularly estimated by maximum likelihood estimation (MLE) (e.g., Ord, 1975).[7] In this paper, we follow the MLE procedures available in the 'spdep' package in R.[8]

[6] For the construction of spatial weight matrices, we used GeoDa 1.6.5 for the threshold-based construction and the "spdep" package on the R 3.1.1 platform for other types of construction, including k-nearest, distance decay, and village neighbor.

[7] The use of least squares regressions would suffer severe endogeneity bias unless properly treated with valid instrumental variables. A prime example of success is the 2SLS estimations conducted by Bramoullé et al. (2009), in which higher-degree neighbors are adopted for identifying instruments of which the validity is assured by the test for necessary and sufficient conditions for identification. Recently, their feat was precisely followed by Krishnan and Patnam (2014) to study farmer-to-farmer technology dissemination in Ethiopia using IV. Another viable method is generalized methods of moments (GMM), suggested by Lee (2007) and further developed by Lin and Lee (2010) and Elhorst (2010) by discussing the pros and cons of these different methods.

[8] R is free computational software. We used version 3.1.1. For more details, visit http://cran.r-project.org/.

Provided that our neighborhood structures satisfy the necessary and sufficient conditions for the identification of neighborhood effects (see Section 4.3), we assume that the MLE procedure of the spatial econometric models stands.

4.3. Test for social effects identification

As discussed in Section 3, we follow the procedure of the test for necessary and sufficient conditions for social effect identification provided by Bramoullé et al. (2009). In the most general case of allowing for the existence of correlated social effects, the identification condition is characterized as follows:[9]

Proposition. *Consider Eq. (3). Suppose that* $\rho_3\alpha_3 + \beta_3 \neq 0$. *If the matrices* $\boldsymbol{I}$, $\boldsymbol{W}$, $\boldsymbol{W}^2$, and $\boldsymbol{W}^3$ *are linearly independent, social effects are identified.*[10] *Next, suppose that* $\boldsymbol{W}^3 = \gamma_0\boldsymbol{I} + \gamma_1\boldsymbol{W} + \gamma_2\boldsymbol{W}^2$. *If rank*$(\boldsymbol{I} - \boldsymbol{W}) < N - 1$ *and* $2\gamma_0 + \gamma_1 + 1 \neq 0$, *social effects are identified. In contrast, if rank*$(\boldsymbol{I} - \boldsymbol{W}) = N - 1$, *social effects are not identified since higher order network terms of* $\boldsymbol{X}$ *cannot be used as valid instruments to estimate the model consistently.*

5. Survey data

5.1. Agricultural and socioeconomic variables

Agricultural and socioeconomic variables constitute the vector of variables *X*. This paper employs variables for the farmer's age (year), gender (dummy = 1, if male), years of schooling (year), field size (ha), assets (Philippine Pesos, P hereafter)[11], household size in terms of the number of household members, and ratio of females in the household (proportion), as well as the pricing system for irrigation water (dummy = 1, if volumetric and =0, if area-based pricing)[12] to test whether any of these variables can explain the observed social behavior.[13] We expect that the groups facing volumetric incentives will contribute more to public goods because the demand for collective water management to save water is higher under that pricing system (positive marginal cost of water) than under the area-based pricing system (zero marginal cost). The average is calculated over four crop seasons for field size, assets, household size, and female ratio. The logarithm of the assets variable better approximates a normal distribution. The sample means and standard errors of these variables are summarized according to irrigation status in Table 1.

To validate the comparison of neighborhood effects between the irrigated and rainfed samples, despite sampling rainfed farms from an area similar to the irrigated area, it must be demonstrated that the difference in social behavior arises from the difference in the way farmers interact due to their ecosystem rather than from the difference in intrinsic demographic factors. The rightmost column in Table 1 presents the *t*-test diagnostics for the mean differences in the mentioned variables between the two ecosystems. The only highly significant difference is observed in field size. From our observations in the field, rainfed farmers tended to overestimate the size of their plots, while irrigated farmers knew the exact dimensions of their fields because these were officially measured when the irrigation system was introduced.[14] Nevertheless, attention is paid to this variable when discussing the regression results. For all other variables, however, the mean difference is neither statistically significant nor large in magnitude. Therefore, we assume that there is little intrinsic difference between the irrigated and rainfed farmers in the sample, except the irrigation system itself.

5.2. Experimental games design

Our dependent variables are the indicators of social behavior, which are the results of our artifactual field experiments. To elicit farmers' social behavior, the IRRI conducted the following two types of experimental games utilizing a standard protocol: (1) the dictator game for measuring altruistic behavior and (2) a repeated public goods game for measuring behavior contributing to public works.[15]

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[9] For derivation, read the paragraphs related to Proposition 5 in Bramoullé et al. (2009).

[10] As suggested by Bramoullé et al. (2009), one easy way to check whether these four matrices are linearly independent is as follows. First, vectorize each matrix, that is, stack its columns on top of each other. Second, verify whether the matrix formed by concatenating these stacked vectors has rank four.

[11] Assets are included as an indicator of farmers' general wealth. The measure includes agricultural, non-agricultural, and livestock assets.

[12] Under the current regulations, each farmer provided with irrigation must pay the National Irrigation Administration an irrigation service fee equivalent to 150 kg of paddy per hectare per season (an area-based pricing system). For the sake of another research project, half of the WUGs were randomly selected to receive a monetary equivalent to their water savings based on consumed volume (volumetric reward system), while the other half was paid under the current pricing method.

[13] To address multicollinearity, the coefficient of correlation was calculated for all combinations of the variables included in any regression and was confirmed to be, at most, 0.35 in absolute terms.

[14] We compared farmers' estimates and GPS measurements for some rainfed farms and observed a tendency to overestimate size.

[15] We followed the experimental protocols of Carpenter et al. (2004), Schechter (2007), Carpenter and Seki (2011), and Aoyagi et al. (2014). The experiment was conducted in two locations: the National Irrigation Administration regional office and a community hall. We conducted one full session per day for six consecutive days to complete the experiment for the entire sample. The participants were strictly prohibited from revealing the contents of the experiment until the last day of the experimental period. A show-up fee of 150 Philippine pesos (P, hereafter) was paid to the participants in two payments of P 50 at the beginning of the experiment and P 100 at the end of the experiment for participants who followed instructions and completed the game. At the time of the experiment (September, 2011), one US dollar was equivalent to approximately P 43, and the typical daily wage rate for agricultural labor was P 200.

Table 1
Descriptive statistics for agricultural and socioeconomic variables by irrigation availability.

	(1) Overall (N = 239)	(2) Irrigated areas (N = 132)	(3) Rainfed areas (N = 107)	(4) t-Test for mean difference $\|(3) - (2)\|$ [p-Value]
Volumetric pricing dummy		0.561		
		(0.498)		
Age	51.138	49.689	52.925	3.236
	(12.086)	(12.248)	(11.692)	[0.039]**
Gender dummy	0.707	0.758	0.645	0.113
	(0.456)	(0.430)	(0.481)	[0.057]*
Years of schooling	6.364	6.144	6.636	0.492
	(3.037)	(2.922)	(3.166)	[0.214]
Ln asset	10.705	10.444	10.724	0.280
	(1.097)	(1.193)	(1.034)	[0.813]
Field size (ha)	1.449	1.167	1.796	0.629
	(1.013)	(0.682)	(1.229)	[0.000]***
Household size (head count)	5.959	6.144	5.731	0.413
	(2.305)	(2.321)	(2.275)	[0.169]
Household female ratio	0.499	0.484	0.518	0.035
	(0.162)	(0.148)	(0.177)	[0.103]†

Note: The sample means are presented. The standard deviations are in parentheses. ***, **, *, and † indicate 1%, 5%, 10%, and 15% statistical significance levels, respectively, for the mean difference between irrigated and rainfed areas. For the mean difference, absolute values are presented.
Source: Authors' calculation utilizing data collected by IRRI.

5.2.1. *The dictator game*

This game was played by an arbitrary pair of individuals: a dictator and a receiver. The dictator was not informed who his or her partner was, and vice versa. The dictator was given P 100, which was equivalent to two-thirds of the daily wage for a typical farmer in the study area, while the receiver was not given money. Then, the dictator was asked to select the amount $x \in \{0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100\}$ to transfer to the receiver whereby the receiver was someone in the same village.[16] We specified that the receiver was a person from the same village rather than anybody in society to allow the participants to feel spatial proximity with the receiver. The dominant strategy for a person behaving as a *Homo economicus* is to transfer no money. Therefore, the reported amount was considered an indicator of each dictator's altruistic behavior within the village community. The game was a one-shot interaction.

5.2.2. *Two-rounds of the public goods game with monitoring and a message*

In the repeated public goods game experiment, participants were sorted into groups of four persons within the same village but were not informed of the identity of their group members. Then, each member was given P 100 and asked to select an amount $x \in \{0, 10, 20, 30, 40, 50, 60, 70, 80, 90, 100\}$ to contribute to the group to which he or she belonged. The total amount contributed by all members was doubled and shared evenly among the members, regardless of how much each member contributed. Thus, the payoff function of this game is represented by the following equation:

$$\prod\nolimits_i (x_i, x_j) = (100 - x_i) + \frac{1}{4} \times 2 \times \left(\sum_{j \neq i} x_j + x_i \right).$$

The dominant strategy is no contribution, which reflects the incentive to free ride.

After the first round of the game, participants were allowed to secretly observe the contribution from each member by paying P 1. Then, they were allowed to send an anonymous 'unhappy' signal to a particular member to indicate displeasure at a cost of P 1 per message.[17] This process introduced costly punishment to the game. The second round of the game was played immediately after the first round in the same groups. The amount of the contribution provided a measure of the player's cooperative behavior toward public works or anti-free-riding behavior.

The following games were conducted: dictator game, ultimatum game, trust game, donation game, one-round public goods game, two-round public goods game, and risk game. The final payoff for the experiment was determined by one of these games. The game was picked up by each participant with a lottery at the end of the session. Our experimental instructions appear in supplementary material. Our instructions and the setting of the experiment (English and local language versions) appear in Appendix A of online supplementary materials.

[16] In our experimental games, village is expressed by the local term *barangay*, which is the smallest official administrative unit corresponding to the concept of village in general.

[17] We utilized an 'unhappy' face icon card to convey the message of dissatisfaction. The cards were secretly given to the designated persons at the beginning of the second round of the game played by the same group of partners as in the first round (Carpenter and Seki, 2011).

5.3. Control variables in the public goods game analysis

5.3.1. Risk preference

One critical variable to control for in the estimation of the public goods game is the farmers' individual risk-taking behavior. Some theoretical studies of experimental games and social capital suggest that the propensity to transfer money in games similar to the public goods game in which the subject receives some amount in return from the partner(s) should be closely associated with the willingness to take risks (Cook and Cooper, 2003; Ben-Ner and Putterman, 2001). These reports indicate that individuals' propensity to bet in return-expected games is at least partly explained by their bet in a risk game. Therefore, we also conducted a risk game based on Schechter (2007).[18] The game was played by one person. The player receives P 100 and has an opportunity to bet a portion of this money. The bet was multiplied by 0, 0.5, 1, 1.5, 2, or 2.5. These numbers were determined when the player drew one of six cards bearing one of these numbers with an equal probability of being selected. The amount each player bet was recorded as an indicator of the individual's risk preference.

5.3.2. Message receipt dummy

The message receipt dummy (MRD) takes the value 1 if the individual received at least one message of dissatisfaction from group members after the first round of the public goods game, and 0 otherwise. The MRD variable is included in the regressions for the second round, and a positive coefficient is expected because peer pressure discourages free riding behavior.[19]

5.3.3. Free riding index

The free riding index (FRI) is defined as the product of two variables: (a) the average of the group members' contribution minus one's own contribution, which indicates the relative degree of free riding within the group, and (b) a dummy variable indicating whether one reviewed the other group members' contributions. The FRI is intended to express the recognition of one's own free riding relative to the group members' contribution.[20]

5.3.4. The interaction between MRD and FRI

It is assumed that the effect of receiving messages increases when one is free riding and is aware of this action. To control for this impact, an interaction term between the MRD and FRI is created and included in the regressions.

5.3.5. Contribution in the first round

Another key control variable for the second round of the game is one's own contribution during the first round. Ones and Putterman (2007) note that individuals who offer high contributions during the first round tend to contribute at similar levels during the second round. They conclude that public goods contributions are somewhat persistent even in the presence of sanctions. Thus, without controlling for this tendency, variables such as the MRD would suffer from severe estimation bias.

The descriptive statistics of the variables from the games are summarized in Table 2 with a view toward comparing the two samples. There is no significant difference in the means of these variables except that the dictator game produces slightly higher results in the irrigated areas than in the rainfed areas. Tables 1 and 2 suggest that farmers living in these two ecosystems are not discernibly different. However, the mechanism of determination, particularly regarding neighborhood effects, could be different.

6. Neighborhood structure

Four different weight matrices are constructed that correspond to the four types of neighborhoods considered: (a) plot neighborhood for irrigated farmers, (b) plot neighborhood for rainfed farmers, (c) residential neighborhood for irrigated farmers, and (d) residential neighborhood for rainfed farmers.

The threshold (in kilometers) was 0.959, 1.302, 0.956, and 1.376 for neighborhoods (a), (b), (c), and (d), respectively. Because our purpose is to undertake a fair comparison across neighborhoods, we impose a uniform threshold distance for all neighborhoods. We first employed the longer thresholds (1.302 and 1.376), and the estimation results were by and large statistically insignificant. By contrast, the shorter thresholds led to both significant and insignificant estimates of endogenous social effects depending on the neighborhood and type of social behavior. In the next section, the result based on the uniform threshold of 0.956 km is examined. Other types of neighborhood structures are tested in Section 8 for robustness.

Table 3 summarizes the characteristics of the four weight matrices. The imposition of the uniform threshold distance seems to be reflected in the insignificant mean difference in average neighbor distance between the two ecosystems. The

[18] Return-expected games are games in which the player knows that he or she receives an uncertain payoff as a result of his or her choice of action.

[19] We also estimated regressions utilizing the number of complaints received instead of the MRD. Utilizing this measure, the coefficients were smaller and less significant.

[20] We also substituted variable (a) for the FRI because one's degree of free riding can be indirectly recognized through the return on the contribution. The estimated coefficients were less significant.

Table 2
Descriptive statistics for the results of the artifactual field experiment by irrigation availability.

	(1) Overall (N = 239)	(2) Irrigated areas (N = 132)	(3) Rainfed areas (N = 107)	(4) t-Test for mean difference $\lvert(3)-(2)\rvert$ [p-Value]
Dependent variables				
Dictator game	29.874	32.197	27.009	5.188
	(19.884)	(21.555)	(17.278)	[0.045]**
PG game, round 1	54.226	53.182	55.514	2.332
	(23.030)	(22.080)	(24.194)	[0.437]
PG game, round 2	52.343	51.818	52.991	1.172
	(24.209)	(23.633)	(24.999)	[0.710]
Control variables				
Risk preference	53.473	54.470	52.243	2.227
	(25.718)	(24.380)	(27.345)	[0.507]
PG game, round 1 message receipt	0.280	0.273	0.290	0.017
dummy (MRD)	(0.450)	(0.447)	(0.456)	[0.772]
PG game, round 1 free riding index (FRI)	0.000	0.455	-0.561	1.015
	(15.367)	(14.746)	(16.152)	[0.613]

Note: The standard deviations are in parentheses. ** indicates the 5% statistical significance level for the mean difference between irrigated and rainfed areas. For the mean difference, absolute values are presented.
Source: Authors' calculation utilizing data collected by IRRI.

Table 3
Neighborhood structure: characteristics of the 4 weight matrices.

	Field plot neighbors			Residential neighbors		
	(1) Irrigated areas	(2) Rainfed areas	(3) t-Test for mean difference $\lvert(2)-(3)\rvert$ [p-Value]	(4) Irrigated areas	(5) Rainfed areas	(6) t-Test for mean difference $\lvert(5)-(4)\rvert$ [p-Value]
Weight code	(a)	(b)		(c)	(d)	
Number of observations	131	107		132	107	
Total number of links	860	1176		866	1296	
Non-zero weights (%)	5.01	10.27		4.97	11.32	
Average number of neighbors per	6.565	10.991	4.426	6.561	12.075	5.514
person	(2.649)	(4.292)	[0.000]	(3.119)	(5.275)	[0.000]
Average distance between	0.603	0.589	0.013	0.583	0.581	0.002
neighbors (km)	(0.236)	(0.245)	[0.223]	(0.243)	(0.251)	[0.847]

Note: Threshold distance = 0.956 (km). The threshold distance is the distance that ensures that, for any one of the four neighborhood structures, there is at least one neighbor for every observation. Standard deviations are in parentheses.

average number of neighbors per individual and the average distance between neighbors are in a trade-off relationship. The t-test suggests that farmers have more neighbors in the rainfed areas than in the irrigated areas. We control for this in the robustness check by employing a different weight matrix.[21]

7. Results

7.1. Identification test

The test for necessary and sufficient conditions for the identification of neighborhood effects (Section 4.3) was conducted on each of the four neighborhood structures. First, equation $\rho_3\alpha_3 + \beta_3 \neq 0$ was upheld for all cases, which is implied by Tables 5–7. Second, it held that the four matrices $\boldsymbol{I}$, $\boldsymbol{W}$, $\boldsymbol{W}^2$ and $\boldsymbol{W}^3$ were linearly independent from one another for all four types of $\boldsymbol{W}$.[22] Third, supposing that $\boldsymbol{W}^3 = \gamma_0\boldsymbol{I} + \gamma_1\boldsymbol{W} + \gamma_2\boldsymbol{W}^2$, it is easy to satisfy $2\gamma_0 + \gamma_1 + 1 \neq 0$. Finally, the inequality equation, $rank(\boldsymbol{I} - \boldsymbol{W}) < N - 1$, held true for all four neighborhoods. Hence, neighborhood effects (exogenous and/or endogenous) are identified in all the neighborhoods (a)–(d). This result implies that our chosen neighbor interaction structure ($\boldsymbol{W}$) induces variation in the magnitude of interactions such that each farmer has a unique and different set of neighbors. This result ensures that the spatial regressions in the following sections are not tautological and spurious.

[21] See Appendix B of the online supplementary materials for examples of graphical representation of neighborhood links and the weight matrix.
[22] We vectorized each of the four N-by-N matrices $\boldsymbol{I}$, $\boldsymbol{W}$, $\boldsymbol{W}^2$ and $\boldsymbol{W}^3$ (i.e., for each matrix, the columns are stacked on top of each other), concatenated these four N^2-by-1 vectors into an N^2-by-4 matrix, and conducted a matrix rank test. Consequently, we obtained rank = 4 for all four types of $\boldsymbol{W}$.

7.2. Spatial model selection

To select the appropriate spatial process, Lagrange multiplier tests were performed on the residuals of the cross-regressive estimations for each of the twelve cases (three games multiplied by four spatial weights). The test statistics and our corresponding model choice are summarized in Table 4. The appropriate spatial model is chosen following the procedure outlined in Anselin et al. (1996). In a few cases, an alternative model was also estimated to check the robustness of the estimated parameters.

7.3. Estimation results

Tables 5–7 present the estimation results for the dictator game, the first round of the public goods game, and the second round of the public goods game, respectively.

7.3.1. The dictator game

In the irrigated areas, the endogenous social effect parameter, ρ, is positive and significant for neighborhoods (a) and (c) (in the first model). This finding indicates that farmers' altruistic behavior co-varies positively with their neighbors' altruistic behavior and produces homogeneous social behavior among neighbors. Importantly, it is not a covariate shock but the altruistic behavior itself that generates this mutual dependence, as indicated by the specification diagnosis. Thus, it may be inferred that the introduction and availability of irrigation that requires collective management promoted the social interactions and spatial interdependence of social behaviors, which led to the emergence of a type of social norm. By comparing the magnitude of ρ for (a) and (c), we claim that the endogenous social effect is larger and more significant among residential neighbors than among plot neighbors. Altruistic actions may be more closely associated with daily life activities around residences than with farming activities in the fields.

The only highly significant exogenous social effect is observed for field size among plot neighbors. Among the individual characteristics, the effect of the ratio of females in the household is positive and significant. Existing studies document mixed effects of gender, and our results are consistent with Dufwenberg and Muren (2006), who report that people from certain groups are more generous and equalitarian when women are a majority of the group.

No endogenous social effect is detected in rainfed areas. Farmers' individual plot sizes, however, might exert a positive effect on their altruism. In the absence of intensive collective action, individual farmers' altruistic behavior is at least partially determined by the abundance of his/her land. Rainfed farmers' altruistic behavior seems to be individually rather than interdependently determined.

7.3.2. Public goods game, first round

In the first round of the public goods game, endogenous social effects of contributions are not observed for any of the four neighborhoods. This result may indicate that knowing that they will continue the game and demonstrate their cooperative behavior later, they reveal their personal (or un-domesticated) preference during the first round to see how the others react to it. The influence of neighbors' characteristics (i.e., exogenous social effects) is generally weak as well.

The most decisive individual characteristic is age, which produces negative and highly significant coefficients. Because public goods contribution incorporates an aspect of investment, the decision must be associated with the individual discount rate. According to Read and Read (2004), older people discount time more than younger people, which explains our observed coefficients.[23] Volumetric water pricing has no effect. As expected, risk preference is positively linked with public goods contribution, particularly in irrigated areas, which may be due to a more established investment mind-set in irrigated areas.

7.3.3. Public goods game, second round

In the second round of the public goods game, the farmers' contribution behavior under the influence of monitoring and messaging is expected to appear. In the irrigated areas, parameter ρ is positive and highly significant, especially for plot neighbors. Comparing the magnitude of ρ between (a) and (c), this endogenous social effect is greater and more significant among plot neighbors than residential neighbors, which may be attributed to the collective irrigation management conducted in cooperation with plot neighbors rather than residential neighbors. As in the first round of the game, the exogenous social effects are generally weak. Among the individual characteristics, the effect of age is much less significant than during the first round. Under the pressure of monitoring, the volumetric pricing dummy is positive, but the statistical significance is not high. Contrary to these results, no endogenous social effect is detected in the rainfed areas.

The estimation of monitoring-related control variables deserves close attention. The coefficients on MRD are consistently positive and significant, which indicates that farmers increase their contributions when they explicitly receive unhappy

[23] Some studies present contrasting findings. Chao et al. (2009) observe an insignificant effect of age on time preference, while Aldy and Viscusi (2007) report an inverted U-shaped relationship. Nevertheless, the downward-sloping part of the inverted U may correspond to our results because a majority of our sample farmers are middle-aged or elderly.

Table 4
Diagnostic tests for the spatial regressions.

Game experiment	Dictator game				Public goods game, round 1				Public goods game, round 2			
Neighborhood	Field plot		Residential		Field plot		Residential		Field plot		Residential	
Ecosystem	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed	Irrigated	Rainfed
Weight code	(a)	(b)	(c)	(d)	(a)	(b)	(c)	(d)	(a)	(b)	(c)	(d)
Moran's I	0.042	−0.059	0.131	−0.082	−0.087	0.044	0.004	0.016	0.119	−0.033	0.162	−0.004
	(0.050)*	(0.681)	(0.001)***	(0.896)	(0.849)	(0.011)**	(0.246)	(0.060)	(0.000)***	(0.408)	(0.000)***	(0.164)
	↓	↓		↓	↓	↓	↓	↓	↓	↓	↓	↓
LM on error correlation	0.616		5.332			0.850		0.118	5.001		8.135	
	(0.433)		(0.021)**			(0.357)		(0.732)	(0.025)**		(0.004)***	
LM on lag correlation	3.034		7.854			0.759		0.010	10.961		9.849	
	(0.082)*		(0.005)***			(0.384)		(0.922)	(0.001)***		(0.002)***	
Robust LM on error	12.977		2.540			0.115		0.697	0.375		0.214	
correlation	(0.000)***		(0.111)†			(0.735)		(0.404)	(0.540)		(0.644)	
Robust LM on lag	15.395		5.062			0.024		0.589	6.335		1.928	
correlation	(0.000)***		(0.024)**			(0.878)		(0.443)	(0.012)**		(0.165)	
LM on SARMA	16.011		10.394			0.874		0.707	11.336		10.062	
	(0.000)***		(0.006)***			(0.646)		(0.702)	(0.003)***		(0.007)***	
	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓	↓
Spatial model of our choice	Lag and cross	Cross	Lag and cross	Cross	Cross	Cross	Cross	Cross	Lag and cross	Cross	Cross	Cross
For robustness check			ARAR and cross								Lag and cross	

Note: The *p*-values are in parentheses. ***, **, *, and † indicate 1, 5, 10, and 15% statistical significance levels, respectively.

Table 5
Spatial regressions for the dictator game.

Neighborhood	Field plot		Residential		
Ecosystem	Irrigated	Rainfed	Irrigated		Rainfed
Spatial model	Lag and cross	Cross	Lag and cross	ARAR and cross	Cross
Weight code	(a)	(b)	(c)	(c)	(d)
Endogenous social effect					
ρ	0.239		0.352	0.331	
	(0.078)*		(0.004)***	(0.430)	
Correlated social effect					
λ				0.034	
				(0.948)	
Neighbors' characteristics					
Volumetric pricing dummy	−13.630		−11.492	−11.601	
	(0.089)*		(0.109)†	(0.150)†	
Age	0.123	0.542	−0.105	−0.128	0.957
	(0.740)	(0.365)	(0.763)	(0.763)	(0.133)
Gender dummy	4.382	−6.495	11.062	11.584	2.279
	(0.589)	(0.660)	(0.195)	(0.258)	(0.871)
Years of schooling	−0.750	−1.749	−1.288	−1.322	−1.247
	(0.609)	(0.4428)	(0.391)	(0.383)	(0.679)
Ln asset	−0.887	6.887	5.075	5.230	−1.655
	(0.827)	(0.259)	(0.200)	(0.218)	(0.679)
Field area (ha)	16.206	1.390	8.419	8.361	3.652
	(0.008)***	(0.813)	(0.135)†	(0.194)	(0.501)
Household size	−2.513	−3.030	−1.876	−1.895	2.944
	(0.140)†	(0.410)	(0.275)	(0.317)	(0.448)
Household female ratio	−2.364	−24.554	21.705	23.196	16.928
	(0.942)	(0.439)	(0.440)	(0.500)	(0.701)
Own characteristics					
Volumetric pricing dummy	−2.131		−0.327	−0.371	
	(0.543)		(0.922)	(0.915)	
Age	−0.201	−0.108	−0.263	−0.266	−0.085
	(0.186)	(0.524)	(0.077)*	(0.077)*	(0.622)
Gender dummy	2.914	4.954	3.526	3.605	5.678
	(0.484)	(0.221)	(0.385)	(0.407)	(0.143)†
Years of schooling	0.610	0.429	0.221	0.213	0.197
	(0.341)	(0.488)	(0.734)	(0.748)	(0.766)
Ln asset	−0.374	−0.451	−0.308	−0.290	−0.783
	(0.820)	(0.808)	(0.849)	(0.863)	(0.691)
Field area (ha)	−0.118	2.619	−0.956	−0.920	2.694
	(0.967)	(0.087)*	(0.723)	(0.745)	(0.077)*
Household size	−0.323	0.296	−0.377	−0.387	1.011
	(0.664)	(0.721)	(0.613)	(0.610)	(0.278)
Household female ratio	29.147	0.371	30.608	30.845	0.874
	(0.013)**	(0.970)	(0.011)**	(0.012)**	(0.933)
Intercept	31.840	−33.801	−29.964	−30.609	−33.951
	(0.470)	(0.619)	(0.494)	(0.150)†	(0.558)
Sample size	131	107	132	132	107
Fit of the model					
Multiple R-squared		0.186			0.160
Adjusted R-squared		0.062			0.032
F statistic		1.506			1.252
		(0.125)†			(0.253)
Wald statistic	3.865		11.480		
	(0.049)**		(0.001)***		
LR test				8.159	
				(0.017)**	

Note: The p-values are in parentheses. ***, **, *, and † indicate 1, 5, 10, and 15% statistical significance levels, respectively.

Table 6
Spatial regressions for the public goods game, round 1.

Neighborhood	Field plot		Residential	
Ecosystem	Irrigated	Rainfed	Irrigated	Rainfed
Spatial model	Cross	Cross	Cross	Cross
Weight code	(a)	(b)	(c)	(d)
Neighbors' characteristics				
Volumetric pricing dummy	−9.637		−11.411	
	(0.273)		(0.147)†	
Age	−0.623	0.474	−0.682	−1.203
	(0.131)†	(0.569)	(0.074)*	(0.166)
Gender dummy	−9.676	36.025	−10.821	38.166
	(0.279)	(0.088)*	(0.244)	(0.047)**
Years of schooling	−0.152	0.687	0.533	−1.747
	(0.926)	(0.832)	(0.755)	(0.678)
Ln asset	0.013	−9.226	3.425	−3.442
	(0.998)	(0.278)	(0.440)	(0.525)
Field area (ha)	8.575	−0.260	2.966	6.372
	(0.190)	(0.975)	(0.633)	(0.389)
Household size	−1.822	1.576	1.453	−2.251
	(0.328)	(0.763)	(0.440)	(0.668)
Household female ratio	11.186	19.973	−8.118	12.461
	(0.751)	(0.651)	(0.790)	(0.835)
Own characteristics				
Volumetric pricing dummy	0.221		0.217	
	(0.955)		(0.954)	
Age	−0.450	−0.754	−0.441	−0.704
	(0.008)***	(0.002)***	(0.008)***	(0.004)***
Gender dummy	−4.709	−1.661	−5.778	−2.991
	(0.305)	(0.768)	(0.195)	(0.569)
Years of schooling	0.112	−0.022	0.236	0.219
	(0.876)	(0.980)	(0.744)	(0.808)
Ln asset	2.323	2.006	1.307	1.423
	(0.201)	(0.440)	(0.465)	(0.595)
Field area (ha)	5.586	−2.426	5.754	−2.109
	(0.069)*	(0.257)	(0.054)*	(0.307)
Household size	−0.742	−0.613	−0.575	−0.989
	(0.367)	(0.595)	(0.486)	(0.437)
Household female ratio	20.000	−15.303	18.812	−16.214
	(0.125)†	(0.272)	(0.155)	(0.259)
Control				
Risk-taking behavior	0.227	0.127	0.215	0.124
	(0.006)***	(0.189)	(0.010)***	(0.176)
Intercept	69.559	111.424	39.920	171.388
	(0.153)	(0.241)	(0.411)	(0.031)**
Sample size	131	107	132	107
Fit of the model				
Multiple *R*-squared	0.232	0.203	0.256	0.225
Adjusted *R*-squared	0.117	0.072	0.145	0.097
F statistic	2.012	1.547	2.302	1.762
	(0.016)**	(0.105)†	(0.005)***	(0.053)*

Note: The *p*-values are in parentheses. ***, **, *, and † indicate 1, 5, 10, and 15% statistical significance levels, respectively.

messages from group members.[24] This result is consistent with studies that demonstrate the effectiveness of costly punishments in both the laboratory and the field (Gächter and Fehr, 2000; Ostrom, 2000; Bowles and Gintis, 2002; Balafoutas and Nikiforakis, 2012). The FRI produces a positive coefficient only in the irrigated areas. Because this index represents farmers' awareness of their own free riding behavior, it indicates that irrigated farmers are willing to adjust their contribution voluntarily when they notice their own over- or under-contribution. This result provides evidence of irrigated farmers' tendency to emulate others, which represents the emergence of social norms. The MRD–FRI interaction term exhibits a positive impact in the irrigated areas, which means the receipt of complaints is even more effective when combined with the awareness of one's own free riding behavior. In other words, in the irrigated areas, free riders are more responsive to messages of dissatisfaction, while in the rainfed areas, farmers respond to complaints uniformly regardless of free riding.

[24] The coefficients are smaller in the irrigated areas. However, the total effect of MRD must incorporate the cross effect of the MRD-FRI interaction as well. Because the interaction term is significant only in the irrigated areas, the total effect of MRD is not considerably different between the two ecosystems.

Table 7
Spatial regressions for the public goods game, round 2.

Neighborhood	Field plot		Residential		
Ecosystem	Irrigated	Rainfed	Irrigated		Rainfed
Spatial model	Lag and cross	Cross	Cross	Lag and cross	Cross
Weight code	(a)	(b)	(c)	(c)	(d)
Endogenous social effect					
ρ	0.332			0.284	
	(0.001)***			(0.004)***	
Neighbors' characteristics					
Volumetric pricing dummy	1.337		11.436	−6.470	
	(0.831)		(0.076)*	(0.258)	
Age	−0.317	−0.884	−0.276	−0.221	−0.674
	(0.289)	(0.205)	(0.377)	(0.418)	(0.360)
Gender dummy	0.439	9.041	−3.750	−1.077	26.052
	(0.945)	(0.611)	(0.627)	(0.874)	(0.117)†
Years of schooling	−2.103	2.285	1.360	0.428	4.210
	(0.070)*	(0.403)	(0.331)	(0.731)	(0.241)
Ln asset	2.964	0.451	−1.520	−1.265	−3.320
	(0.354)	(0.950)	(0.680)	(0.694)	(0.469)
Field area (ha)	0.574	5.710	8.166	3.265	−2.221
	(0.903)	(0.422)	(0.111)†	(0.480)	(0.723)
Household size	−0.577	4.337	0.798	0.224	−1.021
	(0.670)	(0.333)	(0.606)	(0.868)	(0.817)
Household female ratio	−8.270	28.879	35.690	−28.779	−52.340
	(0.742)	(0.445)	(0.157)	(0.189)	(0.299)
Own characteristics					
Volumetric pricing dummy	3.199		3.314	4.083	
	(0.243)		(0.280)	(0.128)†	
Age	0.167	−0.207	0.179	0.187	−0.158
	(0.170)	(0.336)	(0.193)	(0.120)†	(0.470)
Gender dummy	2.492	−0.221	0.690	2.059	1.908
	(0.438)	(0.963)	(0.849)	(0.517)	(0.666)
Years of schooling	0.371	0.050	0.385	0.366	0.612
	(0.466)	(0.945)	(0.516)	(0.481)	(0.423)
Ln asset	1.746	1.451	1.110	1.330	1.629
	(0.171)	(0.512)	(0.447)	(0.297)	(0.480)
Field area (ha)	−0.716	−2.502	1.028	0.302	−3.535
	(0.749)	(0.166)	(0.681)	(0.890)	(0.045)**
Household size	0.613	0.255	0.567	0.517	−0.808
	(0.291)	(0.794)	(0.405)	(0.384)	(0.466)
Household female ratio	7.872	−5.450	2.114	5.034	−7.025
	(0.393)	(0.659)	(0.846)	(0.598)	(0.580)
Controls					
Risk-taking behavior	0.126	0.237	0.193	0.161	0.265
	(0.034)**	(0.004)***	(0.006)***	(0.008)***	(0.001)***
Round 1, message D	7.312	10.625	7.139	7.416	10.782
	(0.039)**	(0.063)*	(0.080)*	(0.036)**	(0.059)*
Round 1, free riding index (FRI)	0.212	0.014	0.232	0.266	0.046
	(0.090)*	(0.939)	(0.090)*	(0.026)**	(0.800)
Round 1, message D × FRI	0.440	−0.349	0.471	0.419	−0.297
	(0.044)**	(0.247)	(0.053)*	(0.047)**	(0.319)
Round 1, result	0.847	0.532	0.821	0.840	0.537
	(0.000)***	(0.000)***	(0.000)***	(0.000)***	(0.000)***
Intercept	−56.946	−19.940	−2.661	−19.659	70.045
	(0.117)†	(0.803)	(0.949)	(0.587)	(0.309)
Sample size	131	107	132	132	107
Fit of the model					
Multiple *R*-squared		0.510	0.591		0.514
Adjusted *R*-squared		0.403	0.513		0.408
F statistic		4.764	7.558		4.840
		(0.000)***	(0.000)***		(0.000)***
Wald statistic	13.042			9.141	
	(0.000)***			(0.002)***	

Note: The *p*-values are in parentheses. ***, **, *, and † indicate 1, 5, 10, and 15% statistical significance levels, respectively.

Table 8
Robustness checks for the spatial regressions: dictator and public goods games, round 1.

Neighborhood	Field plot		Residential	
Ecosystem	Irrigated	Rainfed	Irrigated	Rainfed
Dictator game				
[***W1***] 6-nearest neighbors model				
Spatial model	Lag and cross	Cross	Lag and cross	Cross
Endogenous social effect (ρ)	0.195		0.238	
	(0.148)†		(0.101)†	
Sample size	131	107	132	107
[***W2***] 1/d distance decay neighborhood model				
Spatial model	Lag & Cross	Cross	Lag & Cross	Cross
Endogenous social effect (ρ)	0.484		0.487	
	(0.151)		(0.150)†	
Sample size	131	107	132	107
[***W3***] Village neighbors model				
Spatial model			Cross	Cross
Endogenous social effect (ρ)				
Sample size			129	107
Public goods game, round 1				
[***W1***] 6-nearest neighbors model				
Spatial model	Cross	Cross	Cross	Cross
Endogenous social effect (ρ)				
Sample size	131	107	132	107
[***W2***] 1/d distance decay neighborhood model				
Spatial model	Cross	Cross	Cross	Cross
Endogenous social effect (ρ)				
Sample size	131	107	132	107
[***W3***] Village neighbors model				
Spatial model			Cross	Cross
Endogenous social effect (ρ)				
Sample size			129	107

Note: The p-values are in parentheses. ***, **, *, and † indicate 1, 5, 10, and 15% statistical significance levels, respectively.

This result may indicate the emergence of a stronger community mechanism in the irrigated areas, with which a social norm is complemented to effectively prevent free riding. The risk preference in the irrigated areas is positive in the second round as well. This indicates that if one's neighbors become risk averse for whatever reason, they will reduce their contribution, and, through neighborhood effects, he or she will eventually reduce his or her contribution. This is a possible downside of neighborhood effects. Finally, the contribution during the first round of the game plays a crucial role as a control variable.

7.4. *Summary of findings*

The findings are summarized as follows. First, neighborhood effects were generally found among geographical neighbors in the study sites. In particular, the endogenous social effects among irrigated farmers are observed in the estimations of the dictator game and the second round of the public goods game. The exogenous social effects are minor; no correlated social effects are observed. Hypothesis 1 is thus supported to the extent that it depends on the irrigation availability and the type of social behavior. Second, there is a clear contrast between the results from the two ecosystems. The endogenous social effects and the impact of FRI are observed only in the irrigated areas, which supports Hypothesis 2. Third, comparing plot and residential neighborhoods, the interdependence of public goods contribution under monitoring is stronger among plot neighbors. Therefore, Hypothesis 3 is supported.

8. Robustness to alternative weight matrices

There are different methods of defining the weight matrix. This section briefly examines the robustness and validity of our results by introducing three alternative definitions of neighbors. A popular alternative to the use of a threshold distance is to impose a k-nearest-neighbor criterion in which a specified number of nearest neighbors (k) to each individual are defined as neighbors, so that everyone has the same number of designated neighbors. Here, we set k at six because this is approximately the average number of neighbors by our main model in irrigated areas where the endogenous social effects were found. We denote this matrix [***W1***]. Endogenous social effects were not found in rainfed areas due possibly to the inclusion of many neighbors that causes noise in identifying true neighbor effects. Therefore, it is interesting to examine the six-nearest-neighbor structure applied to both ecosystems.

Table 9
Robustness checks for the spatial regressions: public goods game, round 2.

Neighborhood	Field plot		Residential	
Ecosystem	Irrigated	Rainfed	Irrigated	Rainfed
[***W1***] 6-nearest neighbors model				
Spatial model	Lag and cross	Cross	Error and cross	Cross
Endogenous social effect (ρ)	0.358 (0.001)***			
Correlated social effect (λ)			0.376 (0.006)***	
Round 1, message D	7.480 (0.036)**	11.148 (0.057)*	8.020 (0.022)**	9.405 (0.109)†
Round 1, free riding index (FRI)	0.229 (0.065)*	0.039 (0.833)	0.296 (0.013)**	0.047 (0.805)
Round 1, message D × FRI	0.453 (0.038)**	−0.252 (0.405)	0.350 (0.096)*	−0.242 (0.445)
Sample size	131	107	132	107
[***W2***] 1/*d* distance decay neighborhood model				
Spatial model	Cross	Cross	Cross	Cross
Endogenous social effect (ρ)	0.510 (0.097)*		0.514 (0.095)*	
Round 1, message D	7.370 (0.031)**	11.860 (0.040)**	7.365 (0.030)**	11.860 (0.040)**
Round 1, free riding index (FRI)	0.289 (0.015)**	0.029 (0.889)	0.291 (0.014)**	0.029 (0.889)
Round 1, message D × FRI	0.309 (0.150)†	−0.221 (0.472)	0.305 (0.154)	−0.221 (0.473)
Sample size	131	107	132	107
[***W3***] Village neighbors model				
Spatial model			Cross	Cross
Endogenous social effect (ρ)				
Round 1, message D			7.144 (0.058)*	9.405 (0.109)†
Round 1, free riding index (FRI)			0.298 (0.020)**	0.047 (0.805)
Round 1, message D × FRI			0.338 (0.136)†	−0.242 (0.445)
Sample size			129	107

Note: The *p*-values are in parentheses. ***, **, *, and † indicate 1, 5, 10, and 15% statistical significance levels, respectively.

Both the threshold distance and *k*-nearest-neighbor methods employ binary weight models, i.e., observations are defined as either neighbors or non-neighbors. An alternative method would allow the neighborhood influence to decrease gradually with distance. We consider a distance decay function using the first order inverse distance, and this matrix is denoted [***W2***].[25]

Finally, we examine a model in which all of the residents of the same village are considered neighbors and those outside the village are non-neighbors. This matrix is denoted [***W3***]. Defining neighborhoods by administrative unit is a method that has been employed in conventional neighborhood effect studies, although not with spatial econometrics techniques. Note that plot neighborhood is not defined in this approach because village membership is based on residency.

The estimation results using these three weights are presented in Table 8 for the dictator game and round 1 of the public goods game and Table 9 for round 2 of the public goods game. Only the variables of major interest are displayed.[26] For ***W1***, positive endogenous social effects are observed in the irrigated areas but to a lesser extent than in the main model. In the dictator game, the effects are smaller and statistically less significant. In round 2 of the public goods game, the effect is as large and significant in the plot neighborhood as in the main model, while a correlated social effect is detected for the residential neighborhood. Overall, the results of the 6-nearest-neighbor model suggest robustness of the main results.

For ***W2***, the statistical significance of the endogenous social effects is notably lower, though the magnitude is larger. This observation suggests that distant residents do not contribute as strongly to behavioral interdependence as close neighbors do because the model considers influences from quite distant neighbors to a certain extent. Still, the results from ***W2*** also support the robustness of the main results. With ***W3***, neither the spatial lag nor ARAR model is suggested by the spatial diagnostic tests in either game. In other words, no endogenous social effect is found in this neighborhood model. The average number of village members is 24, and thus, village members who reside far away are modeled in to the same extent as those quite close, which may obscure behavioral interdependence.

[25] A number of different methods to define non-threshold models exist, e.g., exponential decay.
[26] See Appendix C of the online supplementary materials for the neighborhood characteristics and the full regression results.

These robustness checks seem to reveal two points: first, our main results are robust to the use of alternative weight matrices. In particular, the estimation with ***W1*** verifies that the difference in the average number of neighbors between the two ecosystems in our main model is not the cause of the presence and absence of a behavioral interdependence. Second, the threshold distance model is superior to the three variants for modeling the spatial interdependence in social behaviors. In the context of irrigation management, distance, rather than village membership or number of neighbors, may play a key role in promoting social interaction.

9. Limitation

While our result is expected to offer an interesting contribution to the literature, it would have been even more convincing if there had been a dynamic data set with a baseline. Admittedly, such data are unavailable, which allows one to wonder whether our result should be interpreted as evidence of a treatment effect of irrigation. One might suspect that the result possibly represents a selection effect, i.e., the irrigation scheme was introduced to an area where people had already been better networked.

To provide a clue to this issue, Section 2 described the background on why the irrigation scheme was introduced into the currently irrigated area, and why not in the rainfed area and Section 3 illustrated that the sampled residents have not undergone relocation due to the introduction of irrigation. This background information is in support of a certain extent of random and exogenous treatment. Nonetheless, in the absence of panel data, a formal assessment of the causality is not possible at this stage, and will be left to our future endeavors. Therefore, the main claim of this paper is limited to that the neighborhood effect is observed, and it is stronger in the irrigated areas, with humble inference as to the role of collective irrigation management.

10. Discussion and concluding remarks

The neighborhood effects found in our study area provide some insight into the link between behavioral patterns and social norms for pro-social behavior. Our key result is that farmers' altruistic and contribution behaviors are influenced by their neighbors only in the irrigated areas. Provided that there is no innate difference in behavioral traits between irrigated and rainfed rice farmers, which is partially supported by the descriptive tables and, more importantly, by the background of the irrigation project, our results suggest that the collective action required in gravity irrigation management among plot neighbors likely induces social norms in which farmers exhibit social behaviors similar to their neighbors'. However, this finding also implies that outcomes may not necessarily be pro-social because neighborhood effects can reduce the level of the high contributors' contributions to their neighbors' level. Vicious cycles in conformism norm dissemination are a possible process.

Our analysis also indicates that farmers' positive corrective responses to their own free riding behavior in the irrigated areas may reflect the induced social norms through which individuals' free riding acts are voluntarily corrected. While the message of dissatisfaction, a type of costly punishment, effectively increases contributions in both ecosystems, the effect is greater on free riders in the irrigated areas. Increased demand for cooperative resource management in the real world also promotes a community mechanism of punishment that complements the function of social norms. Cooperative activities such as the maintenance of communal spaces and the construction of village roads are equally common in both irrigated and rainfed areas; however, behavioral differences between the two ecosystems are detected. This is a thought-provoking observation on the possible impact of increased demand for collective irrigation water management on the evolution of social norms and community mechanisms.

The irrigation systems in the study site were introduced two years before the data collection, which implies that interventions such as the construction of gravity irrigation systems can generate rather rapid changes in the beneficiaries' behavioral patterns. This implication may not be surprising: Goette et al. (2012) observe that cooperation and norm enforcement in experimental games emerge after a few weeks of group formation in real society. However, the dynamism and sustainability of new norms and community mechanisms amid increasing heterogeneity among farmers, as well as the experience of success or failure in irrigation management, are important issues to be explored by future research.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.jebo.2015.04.022.

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