Networks, Finance, and Development: Evidence from Hunter-Gatherers*

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Abstract

This paper sheds light on the relationship between social networks and market incompleteness in an Amazonian hunter-gatherer society. In that economy, individuals enter informal contracts to finance, besides their foraging-farming activities, relatively risky human capital investments in pursuit of employment outside the villages. While the default financing contract can be characterized as debt, insurance in the form of equity-like financing is only available from fellow villagers. However, in order to maintain the stability of the village networks, human capital investments are underfunded with insurance. I show that this capital market imperfection potentially leads to substantial underinvestment in human capital, and calibrate the counterfactual efficiency gains from completing the market. (*JEL* O12, O16)

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1 Introduction

Social and other informal networks substitute for institutions in developing countries, and there exists ample documentation of the benefits of such networks – for utility and for material success (e.g., Rosenzweig, 1988, Grimard, 1997, Bayer et al., 2008). However, very little is known – empirically – about the cost of maintaining networks (Banerjee and Newman, 1998), which would be required to assess the actual performance of networks in replacing a market structure. This paper sheds light on the relationship between social networks and market incompleteness in an Amazonian hunter-gatherer society, the Tsimane', and derives the counterfactual efficiency gains from completing the market in that economy.

My analysis is based on five-year panel data from an in-depth account of recorded activities in 14 villages in Amazonian Bolivia where the Tsimane' reside. Villagers allocate their time to foraging-farming and human capital. The Tsimane' typically do not speak Spanish, but studying it opens doors to lucrative wage labor. Investments in human capital and their returns are well understood in this economy: villagers can seek schooling at virtually all ages, and subsequently work on farms, at schools, and eventually in administration.

The trade-off between foraging-farming and human capital accumulation is typical of underdeveloped economies, and reflects the fundamental setup for the transformation from agriculture to market sophistication and industrialization. To develop a general understanding of that transformation, and to evaluate how markets contribute to the latter, one would want to scrutinize allocation mechanisms and their impact on household wealth composition. In the absence of markets, social organization forms – such as networks – determine the rules of exchange and distribution. Against this background, I study the relationship between growth-enhancing human capital investments and the structure of social interactions in Amazonian Bolivia.

Given their small size, every village can be considered a tight network, and such network affiliation turns out to have explanatory power for implicit financing contracts in- as opposed to outside the villages. These funds are used to finance investments in foraging-farming and human capital. Hence, inefficienct investment levels can in part be traced back to imperfections of the capital market. The main imperfection is related to the availability of financing contracts: while the default financing contract can be characterized as debt, insurance in the form of equity-like financing is only available within villages. Here, equity arrangements are borrowings where repayment is proportional to the debtor's income. However, as human capital investments are detrimental to maintaining a critical village network size, there is underfunding of human capital with equity/insurance, forcing some villagers to contract with outsiders instead. As is well known, the presence of such financial frictions can lead to inseparability of investment and financing decisions. Human capital is potentially underfunded with equity, and the latter is not available everywhere in the villages, so whoever demands such a contract runs the risk of attaining debt rather than equity/insurance, which can lead to underinvestment in human capital.

In order to determine who is affected by this financial friction, and is thus susceptible to underinvestment, I distinguish villagers by their degree of connectedness with the outside world. More conservative villagers are likely to rely more heavily on their village networks, and that trait is strongly correlated with mating preferences that preserve the strength of the village networks. Roughly three-quarters of the population practice cross-cousin marriage and deem any deviation from that practice unacceptable, whereas the remainder do not. Thus, the preferential system of cross-cousin marriage can be considered a boundary that splits each village network into two groups. Due to intergenerational transmission of mating preferences, this village network structure proves to be exogenous, which enables the measurement of the impact of group affiliation on economic outcomes. I find that the group practicing cross-cousin marriage is more invested in traditional assets, has lower income, and performs worse on human capital measures despite similar learning productivity. These aggregate differences partly reflect (risk) preferences, but may also result from inefficiencies that arise due to underfunding in villages.

To identify potential inefficiencies in the human capital investment process, I use group-specific learning productivity as an instrument for unobserved characteristics that govern contract preferences. In the data, the most capable members of the group practicing cross-cousin marriage are more likely to receive equity whereas the counterparts in the remaining village network are more likely to receive debt. Upon randomization of contract assignments, I find that a subset of villagers who used debt would have invested more in human capital if they had received equity/insurance, and I reveal this group to be the group practicing cross-cousin marriage. I interpret this as evidence that members of the inward-looking group that rely more on village structures than the market economy evolving around them potentially exhibit greater risk aversion than other villagers.

The last part of the paper then calibrates the efficiency loss stemming from the limited availability of equity by quantifying how much more risk averse villagers (who would typically demand equity) would invest in human capital if they could always attain equity/insurance. I show that this efficiency loss potentially has very high explanatory power for the earnings gap between the two groups.

This paper presents, and is based on, some of the merits of studying hunter-gatherers. A simplistic economy such as the one in Amazonian Bolivia (two assets, two contracts) aids the identification of the effect of financial frictions on investment outcomes. Given that the allocation of time between foraging-farming and human capital spans the space of variation in economically meaningful decisions of the villagers, financing contract choice is the only explanatory variable for human capital outcomes that potentially reflects (risk) preferences. This way, the simplicity of the Tsimane' economy reduces the risk of omitting important measures of revealed preference, and can thus serve as a quasi-laboratory setting for testing economic models.

1.1 Related Literature

This paper touches on various issues at the intersection of finance and development. Economists have a long-standing interest in the relationship between financial development and growth: while Greenwood and Jovanovic (1990) characterize the impact of financial intermediation on growth through returns on capital, Acemoglu and Zilibotti (1997) focus on financial diversification at different stages of development, and argue that well-developed financial markets can be expected to facilitate a reduction in growth volatility through better diversification opportunities and more productive use of funds. Most closely related to the paper at hand, Greenwood, Sanchez, and Wang (2010) embed costly state verification in the standard growth model, and derive the efficiency gains from technological progress in financial intermediation. The vast literature on the topic is surveyed by Levine (1997, 2005). Accordingly, the number of coexistent empirical approaches is proportional to the channels through which financial deepening may impact economic development. For instance, Rajan and Zingales (1999) define financial development as a reduction in the agency cost of external finance, and find larger effects of financial development in industries that are in greater need of external finance. In the context of a developing country (Thailand), Townsend and Ueda (2006) shed light on the link between financial development and inequality by calibrating the average movements in financial deepening, inequality, and growth. To the extent that financial intermediaries represent contracting institutions in general, this paper is also related to the empirical work of Acemoglu, Johnson, and Robinson (2001) as well as Acemoglu and Johnson (2005).

The spirit in which this paper analyzes financial contracts and their link to investment decisions is akin to that in Tirole (2006). Using a similar framework in a developing country context, Fischer (2010) presents experimental evidence of the relationship between risk taking in investment decisions and financial contract design. The investment class I focus on is human capital. The empirical characterization of that investment class (e.g., returns to human capital) has been the subject of scrutiny in many studies. While some contributions (e.g., Williams, 1978, and Palacios-Huerta, 2003) focus on the returns to human capital and the investment process, others (e.g., Jacoby and Skoufias, 1997, Krebs, 2003, Berk and Walden, 2010, Erosa, Koreshkova, and Restuccia, 2010, as well as Huggett and Kaplan, forthcoming) explore the interaction of human capital accumulation and markets (e.g., the financial sector).

Lastly, in this paper, the analysis of the relationship between financial frictions and human capital investment is embedded in the context of social networks. The strands of literature on networks are multifaceted, and cover characteristics that help explain economic outcomes within and between networks. While there are many different types of networks, kinship networks play a fundamental role in developing countries. Such social networks are shown to foster trust and altruism (Karlan et al., 2009, Leider et al., 2009, Alger and Weibull, 2010). As these traits help enforce informal contracts, they also translate to allocations in networks, e.g., informal insurance or consumption smoothing via risk sharing (Bloch, Genicot, and Ray, 2008, Ambrus, Moebius, and Szeidl, 2010, Angelucci et al., 2010). Through these channels, social networks can affect a wide variety of economic outcomes and sources of inequality, most notably financial access (Banerjee and Munshi, 2004, Kinnan and Townsend, 2010), welfare participation (Bertrand, Luttmer, and Mullainathan, 2000), and labor (im)mobility (Alesina et al., 2010).

2 Description of the Economy and the Data

In this paper, I discuss the Tsimane' of Amazonian Bolivia, a hunter-gatherer society in the Department of Beni. I use a panel data set from a team of anthropologists who recorded the socioeconomic activities of the villagers from 2002 to 2006. Whereas a more detailed account of the traits and developments among the Tsimane' is given by Godoy et al. (2005), I shall focus on those elements that, to a large extent, characterize the economy and thus define the framework for my analysis. Based on the characterization of the economy, this section describes the survey data and the construction of key variables.

2.1 Salient Features of the Village Economies in Amazonian Bolivia

As is typical of native Amazonian societies, the Tsimane' hunt game as well as fish, and practice slash-and-burn agriculture by clearing plots from the forest. Also, most Tsimane' have sufficient land to farm (5.7 ha/person according to Godoy et al., 2006). These foraging-farming activities paired with a lack of exposure to outside institutions established autarky among the Tsimane'. However, since the early 1950s, they opened up to contact with Westerners. That development culminated in the establishment of permanent Protestant missions by the Department of Beni. Upon their arrival, the missionaries played a crucial role in the education of the Tsimane' as the Bolivian government conferred schooling responsibilities upon them; that agreement would last until 1985. The 30-year training period by Protestant missionaries – first in Tumichuco and later in San Borja,[1] which is closer to the Tsimane' territory – left its mark on the present-day situation of the Tsimane'. For instance, most Tsimane' teachers in the villages who speak Spanish were educated by Protestant missionaries, and so was today's elite among Tsimane' bureaucrats working in Bolivia.

[1]San Borja has roughly 19,000 inhabitants and is, on average, three walking hours away from the villages from which the data for this paper are drawn.

The impact of Protestant missionaries on the socioeconomic development of the Tsimane' is symptomatic of the gradual exposure of the Tsimane' to a market economy: the prospects of employment in towns such as San Borja have gained notice among the Tsimane', and schooling is now recognized as an entry ticket to prosperity. Other opportunities arise from interactions with loggers, cattle ranchers, and colonist farmers who buy and trade crops as well as forest goods, and also offer employment. These interactions characterize the Tsimane' income structure: the three sources of income are earnings from the sale of goods, wage labor, and barter. There is great variation in the composition of the villagers' income portfolios, and this paper scrutinizes the villagers' preference structure and relevant market frictions that eventually lead to the observed income inequality.

In the following, I focus on two salient features of the Tsimane' economy that will be at the core of the analysis in this paper. First, I present an exogenous network structure in the economy. Second, I turn to the investment side and consider the process of human capital formation as an alternative to foraging-farming.

2.1.1 Practice of Cross-Cousin Marriage as a Measure of Connectedness

The Tsimane' live in villages which constitute tight networks. There is a general sense of autarky which is manifested in the fact that, if a member of the community leaves the village, he is more likely to move to a town (e.g., San Borja) in order to pursue employment opportunities, rather than another village.[2] However, there is some variation in the degree of connectedness among the Tsimane': while the vast majority in the villages tend to have more conservative views of the outside world and, particularly, the market economy evolving around them, a small group is more open to outsiders (e.g., loggers, cattle ranchers, colonist farmers, merchants in towns, and the government) while interacting also with other Tsimane' in the village. A characteristic that is highly correlated with a more conservative, self-preserving attitude – and thus a low degree of connectedness – are the mating norms that villagers adhere to.

The traditional kind of marriage among the majority of the Tsimane' is cross-cousin mar-

[2]From 2003 to 2006, only six villagers left their communities for other villages whereas 128 villagers changed households in their villages.

riage, i.e., a man should marry his mother's brother's daughter (matrilateral cross cousin) or his father's sister's daughter (patrilateral cross cousin). About three-quarters of the Tsimane' population practice cross-cousin marriage. The preferential system of cross-cousin marriage can be considered a norm that splits each village into two groups: one that practices cross-cousin marriage and deems any deviation from that norm unacceptable, and one that does not impose this mating rule. In fact, Tsimane' who practice cross-cousin marriage believe that, upon death, those who do not comply with this norm become jaguars and eat living people (Godoy et al., 2008).

[Insert Table 1 about here]

In that respect, the mating norms define a network boundary in the villages under scrutiny. The resulting subnetworks differ in size, with the more conservative, inward-looking one based on cross-cousin marriages being the larger group (cf. Table 1). These groups are exogenous insofar as the belief in cross-cousin marriage is conferred by the villagers' parents, and there is no switching to other beliefs upon adolescence. This can be backed up by the data: the majority opinion of the children in a household overlaps with the household heads' reported mating preference in 94.5% of all households, irrespective of the children's age. Throughout the paper, I define an individual to be a member of the large (inward-looking) group if he belongs to a household in which the majority report their intolerance for deviations from the respective mating norm. The remainder of the villagers are assumed to belong to the small (outward-looking) group. Survey questions on attitudes towards others support the role of mating preferences as a proxy for conservative attitudes – mainly intolerance towards non-Tsimane' – and connectedness in the form of exposure to outsiders and other parties in towns. For instance, members of the small group, on average, travel to towns more frequently than members of the large group (13.47 vs. 9.9 times per year, the difference is significant at the 1% level). The small group also reports to have significantly greater tolerance for farmers, ranchers, traders, and institutions (the Bolivian Agrarian Reform Agency).

In order to use the practice of cross-cousin marriage as a measure of connectedness (i.e., openness to outsiders and thus weaker dependence on fellow villagers), one should make sure that the latter is not a sheer consequence of different exposure to the outside market economy through Protestant missionaries in the past. A simple way of testing this is to compare the distributions of self-professed religion in both groups.[3] In both groups, typically, more than 60% indicate to be Catholics and roughly 30% report to be Protestants (with the remainder being split between atheists and adherents of other religions). A two-sample Kolmogorov-Smirnov test reveals that, in every year of the survey, the distributions of self-professed religion do not differ between the two groups.

2.1.2 Human Capital Formation

Having discussed the social network structure in the economy, I now turn to completing the characterization of the action space of the villagers. Despite the prevalence of foraging-farming, the Tsimane' are increasingly aware of the potential returns to schooling. The available forms of schooling are manifold and open to all ages, so schooling is not uncommon even among adults: 40% of Tsimane' villages have a primary school, but no village has a middle or high school (Reyes-García et al., 2007). Protestant missionaries and other local teachers offer training courses in reading and writing for Tsimane' adults, and there also exist other adult educational programs in some villages where Tsimane' adults with a primary school background can complement their education by a high school degree. By attending school, Tsimane' can study Spanish, Bolivia's national language, which enables them to connect with the labor market. A rudimentary command of Spanish is sufficient to take orders, and thus helps gain employment in logging camps, on cattle ranches, and farms of colonist farmers. Further investment in human capital can pay off in the form of employment by the government in towns such as San Borja.

Since there is no mandatory school attendance for children, human capital investment is a choice for Tsimane'. The unique alternative to human capital investment is foraging-farming. Tsimane' with no fluency in Spanish are limited in their ability to assume employment with outsiders – i.e., loggers, cattle ranchers, and colonist farmers – but they do interact with the latter by selling forest goods or rice and other crops from their farms.

A villager allocates his time between foraging-farming and human capital, two different

[3]Given the prominent role of the Protestant missionaries in the education of the Tsimane', one would suspect that the dominance of Protestantism in one group would be correlated with the degree of connectedness and other traits relevant for economic decision-making.

investment classes. To quantify their differences, one can turn to the survey data. A villager who does not attend school, and thus spends his time on foraging-farming, generating income from the sales of goods, has a bi-weekly income of 101.38 on average (with a standard deviation of 336.27). On the other hand, a villager with some knowledge of Spanish whose major income source is wage labor earns a bi-weekly income of 200.20 on average (with a standard deviation of 201.46).[4] To see that education is indeed a necessary condition for wage labor, one can also compare differences in Spanish ability (rated from 0 to 2) between villagers who derive their income solely from wage labor and those who only have income from foraging-farming. The former group demonstrates greater Spanish fluency in both speaking (1.50) and reading (1.20) – the respective differences to the group of forager-farmers are 0.57 and 0.79, respectively, and are significant at the 1% level.

The payoff to education is thus substantial. However, human capital is a risky asset as the empirical likelihood of zero income turns out to be 14.91% lower for foraging-farming than for wages upon schooling.

In order to finance investments in foraging-farming and human capital, villagers may opt, or be required, to borrow money. As I will show in Section 3, the nature of these informal financing contracts varies with the relationship between borrowers and lenders, depending on whether the lender is a fellow villager or an outsider.

2.2 Data

My main data source is an unbalanced five-year survey (2002-2006) comprising 1,814 individuals from 618 households who are located in 14 villages in Amazonian Bolivia. As indicated in Section 2.1.1, the villages can be separated into two groups: a large group that practices cross-cousin marriage and a small one that does not. A household is defined as practicing cross-cousin marriage if more than half of the household members report that marrying anyone but a cross cousin is unacceptable. In Tables 2a and 2b, I present the descriptive statistics for the variables used in the empirical portion of this paper, namely in the total sample and the calibration sample (i.e., the subset of villagers who borrowed a non-zero amount in at least one year) used in Section 6, respectively.

[4] These averages are conditional on non-zero earnings from the respective activity.

[Insert Table 2a about here]

[Insert Table 2b about here]

As for the data gathering process, the villagers are interviewed at the same time of the year for five years. Some variables (most notably earnings and consumption) are measured on a weekly basis for two weeks prior to the interview, others (e.g., money borrowings) are also measured on a two-month or yearly basis before the day of the interview. All tables indicate the time dimension of the variables.

Tables 2a and 2b display the descriptive statistics for two broad classes of variables:[5] assets and income-related variables, as well as human capital. Regarding the former, income is measured as the sum of earnings from sales of goods, wage labor, and barter. Wages always describe earnings from employment with outsiders. Consumption is measured on the household level, and summarizes the consumption of game, fish, eggs, maize, manioc, rice, oil, and bread. Furthermore, there are two types of assets – traditional and modern ones. As opposed to modern assets such as luxury items, traditional assets can be considered assets for production (i.e., foraging-farming): they include domesticated animals and artifacts that form part of traditional culture such as bows or dug-out canoes. Asset borrowings correspond to traditional assets that are borrowed from neighbors or other fellow villagers.

Credit is a key variable. It includes the amount of money borrowed from any other Tsimane'. Extensive data on the sources of financing have been made available to me, i.e., for every recorded transaction, I have information on whether credit was provided from in- or outside the borrower's village. The time dimension of money borrowings is diverse: I have data on weekly borrowings from two weeks prior to the interview, borrowings from two months prior to the interview, and the amount of any borrowings older than two months.

Lastly, I discuss the available measures of human capital. The villagers were asked in every year whether they are currently attending any type of school, and how much schooling (in years) they received so far. A math test (scored on a scale from 0 to 4) is conducted on a yearly basis as well. The ratio of the math score to the number of years of schooling is used

[5] Note that, while the qualitative differences between the two groups are preserved in the calibration sample, some magnitudes are naturally augmented as the latter sample is conditioned on the villagers' borrowing capacity whereas the total sample comprises all household members (including interviewed children) of each group.

as a measure of learning productivity. The most important measure of human capital in this paper is Spanish fluency in both speaking and reading (on a scale from 0 to 2, differentiating between no competence, some knowledge of, and a good command of the Spanish language). The Spanish speaking and reading abilities of the Tsimane' was judged by the surveyors.

3 Organization of Capital

As can be seen in Tables 2a and 2b, the large (inward-looking) group is more invested in traditional assets, has lower income, and performs worse on human capital measures than the small (outward-looking) group. This constitutes a puzzle: what drives these differences between the two groups that are otherwise very similar? Two obvious explanations fail in this context. First, both groups exhibit indistinguishable educational attributes and learning productivity as well as productivity under wage labor, so ability (of relevant kinds) does not seem to drive the human capital and income gaps. Second, the small group is unlikely to generate greater returns to studying Spanish on the basis of higher endowment. To see this, note that the average value of total assets in the small group does not differ from that in the large group. This also rules out that the small group had higher endowments in the past, i.e., before investing in human capital, because then – given that the small group is more heavily invested in human capital which pays more – they should be wealthier than the large group after investing in human capital.

In this paper, I pursue a different approach, namely by explaining differences in investments by their financing counterparts on the villagers' balance sheets. In particular, I investigate whether the same financing sources are available for investments in both foraging-farming and human capital. In the light that human capital investments are individually beneficial but detrimental to maintaining a critical village network size, one might suspect that there is underfunding of human capital at least with network resources. The restricted willingness to finance human capital investments of fellow villagers would constitute a financial friction. As a consequence of that friction, some people might be forced to seek financing outside their villages. For the financial friction to actually matter in terms of allocative efficiency, one would require financing arrangements to be of different nature in- as opposed to outside the village. The following section sheds light on this very issue.

3.1 Implicit Financing Contracts In- and Outside the Villages

Does the form of financial arrangements vary depending on whether the lender is a fellow villager or an outsider? Given the absence of transaction-level data, I construct a measure for yearly repayment of borrowed funds, and test whether repayment is fixed (as in standard debt contracts) or covaries with income (as in insurance or equity arrangements).

In Table 3a, I regress repayment in the form of $\max\{0, -\Delta Total\ borrowings_{it}\}$, i.e., negative yearly changes in total borrowings (defined as the sum of old credit and any amount borrowed two months prior to the interview), on variables indicating whether a villager borrowed from in- or outside his village last period while controlling for the amount of traditional assets (as a proxy for absolute financing needs). I also interact the dummy variables with the borrower's income last period in order to test whether certain lender groups participate in the borrower's investment success. Given that the data do not comprise all changes in credit throughout the year between two interviews, the negative change in total borrowings reflects a lower bound on the total repayment of credit. Furthermore, as the maturity of financing claims is unknown, I run separate regressions for implicit contracts under which a villager borrowed money from in- or outside the village anytime in the past *one or two years* before period t.[6]

[Insert Table 3a about here]

[Insert Table 3b about here]

The results in Table 3a and 3b are similar: borrowing from external lenders implies fixed repayment (significant intercept effect) whereas fellow villagers seem to provide arrangements in which repayment amounts are proportional to the borrowers' income (significant slope effect). In other, more modern terms, financing from outside the village can be characterized as debt whereas equity-like financing, or insurance, is only available within villages. Regarding the latter, the results can be interpreted as indicating that financing in villages consists

[6]Regressions unreported in this paper show that the results are robust to extending maturity up to the maximum in the data, i.e., four years.

of both a debt and an equity component, or that both contracts are available separately. Regressions unreported in this paper also show that a similar repayment structure holds for other transfers as intra-village lenders seem to enforce other transfers (e.g., work on the lenders' fields) in proportion to the borrowers' income. Henceforth, I use the terms "debt" and "equity" for borrowings from outside and within the village, respectively.

The above-discussed results do not account for potential endogeneity. In that respect, a crucial assumption for safeguarding the validity of the comparison between intra- and extra-village financing is the equal presence or absence of hidden information irrespective of the nature of the lender. If certain lenders are better able to assess the types of borrowers, and thus lend more money to the latter types, then the correlation between repayment and income under intra-village equity could be due to superior information on borrower types among villagers.

[Insert Table 3c about here]

Table 3c presents mean annual borrowings from in- and outside the village for debtors at different percentiles of the wage distribution a year later. By doing so, one can examine whether intra-village lenders fund more successful borrowers, which would reveal the findings in Tables 3a and 3b as biased. This concern, however, does not seem to apply here as I find that external lenders provide relatively more funds to top earners than fellow villagers.

Before discussing the potential implications of the existence of different financing contracts in- and outside the villages, I turn to the demand side by exploring the sources of funds that villagers declare as their borrowings in any given year. More concretely, I examine the determinants of the proportion of borrowings that are raised within the village as measured by $Proportion\ Funds\ Borrowed\ from\ Villager_{it} \in [0, 1]$.

[Insert Table 4 about here]

As can be inferred from Table 4, the most capable members of the large group raise a greater proportion of their funds from fellow villagers, and the gap is most pronounced compared to the most capable members of the small group (who tend to raise their funds outside the village).

3.2 Potential Underfunding of Human Capital

Having laid out the contract technology in the Tsimane' economy, I now turn to the question *why* there is equity/insurance in- but not outside the villages. Given that a lender's payoff is more information-sensitive under an equity/insurance contract than under debt, it seems plausible that the issuance of equity contracts becomes more likely among those who can bear the informational cost. This should apply to fellow villagers rather than outsiders, e.g., fellow villagers are more likely to have unconditional monitoring rights than outsiders.

An alternative explanation sought in this paper is that providers of equity/insurance refrain from funding certain investments, restricting the investment space of potential borrowers and thereby lowering the informational cost of enforcing the respective contract. This approach would answer the question as to why there is equity in- but not outside the villages by illuminating *what* villagers insure in general.

As villagers who invest in human capital are more likely to leave their village networks at some point, fellow villagers might refrain from providing equity/insurance for human capital investments in order to maintain the stability of the community. The general tenor of this hypothesis is reflected by Godoy et al. (2005) who report that, although reciprocity and gift giving permeate Tsimane' society (which can be a foundation for risk sharing arrangements), personal misfortune does not evoke sympathy or actions of generosity among the Tsimane'. While idiosyncratic shocks that impact one's earnings from foraging-farming (e.g., a fire or the death of a household member) are rather exogenous, idiosyncratic shocks from human capital are the result of individual efforts of personal advancement.

A way of testing the non-insurability of idiosyncratic human capital shocks is to run risk sharing regressions in the spirit of Cochrane (1991) and Mace (1991) separately for the two groups with different levels of human capital investment.[7] As observed in Tables 2a and 2b, the small group is more heavily invested in human capital than the large group, but – except for the income differences induced by these investments – very similar otherwise. In the following, I hypothesize that the small group is not as well insured against idiosyncratic shocks as the large group, and test the following specifications:

[7] The empirical validity of the non-insurability of idiosyncratic shocks stemming from human capital investment would also affirm the assumption made in this paper that human capital is riskier than foraging-farming.

$$c_{it} = \mu_i + \beta_1 c_{vt} + \beta_2 Income_{it} + \beta_3 X_{it} + \epsilon_{it} \tag{1}$$

and

$$c_{it} - c_{vt} = \mu_i + \beta_2 Income_{it} + \beta_3 X_{it} + \epsilon_{it} \tag{2}$$

if one is willing to assume that $\beta_1 = 1$,[8] as well as

$$\Delta \ln c_{it} = \mu_i + \beta_1 \Delta \ln c_{vt} + \beta_2 Income_{it} + \beta_3 X_{it} + \epsilon_{it} \tag{3}$$

and

$$\Delta \ln c_{it} - \Delta \ln c_{vt} = \mu_i + \beta_2 Income_{it} + \beta_3 X_{it} + \epsilon_{it} \tag{4}$$

if, again, one is willing to assume that $\beta_1 = 1$, where c_{jt} denotes unit j's weekly consumption of game, fish, eggs, maize, manioc, rice, oil, and bread (in bolivianos) in year t, i stands for a household, v denotes the respective village, and X_{it} is a vector of idiosyncratic shock dummies that affect earnings from foraging-farming and from wage labor (i.e., the returns to human capital investments).

[Insert Table 5a about here]

The results, alongside detailed information on the variables, are given in Table 5a. One has perfect risk sharing if the joint hypothesis of a unit coefficient of aggregate consumption and a zero coefficient of income cannot be rejected. I find that household consumption among villagers in the small group varies significantly with income and multiple idiosyncratic shocks, as a result of which the coefficient of aggregate consumption is less than one. On the other hand, throughout all specifications, perfect risk sharing cannot be rejected for the large group which is less invested in human capital. The degree of risk sharing even surpasses that in Indian villages analyzed by Townsend (1994).

As the definition of the groups is correlated with the degree of connectedness, it is sensible to assume that the two groups differ in who they share risk with. To this end, I replace specifications (1) and (3) by:

[8] This specification assumes a unit coefficient of aggregate consumption to avoid a bias of the coefficient on aggregate consumption due to a possible correlation with the error term (Mace, 1991).

$$c_{it} = \mu_i + \beta_1 c_{gt} + \beta_2 \left(c_{vt} - c_{gt}\right) + \beta_3 Income_{it} + \beta_4 X_{it} + \epsilon_{it} \tag{5}$$

and

$$\Delta \ln c_{it} = \mu_i + \beta_1 \Delta \ln c_{gt} + \beta_2 \left(\Delta \ln c_{vt} - \Delta \ln c_{gt}\right) + \beta_3 Income_{it} + \beta_4 X_{it} + \epsilon_{it} \tag{6}$$

where c_{jt} denotes unit j's weekly consumption of game, fish, eggs, maize, manioc, rice, oil, and bread (in bolivianos) in year t, i stands for a household, v denotes the respective village, g represents all villages in the data, and X_{it} is a vector of idiosyncratic shock dummies.

[Insert Table 5b about here]

In all specifications in Table 5b, β_1 is not significantly different from β_2 for the large group, implying that the large group shares risk – and perfectly so – only with fellow Tsimane' in the same village. On the contrary, the small group, as suspected, shares a notable portion of risk with Tsimane' in other villages as β_1 is significantly different from β_2 at least in the specifications using delta logs based on (6).

Overall, one learns that the small group which is more heavily invested in human capital and better connected with outsiders is not perfectly insured against idiosyncratic risk. From this, one can also infer that human capital is likely underfunded with equity/insurance by fellow villagers. As already encountered in, for instance, Munshi and Rosenzweig (2006), network members often cannot pursue higher aspirations without sacrificing some of their network support, which takes the form of insurance in the Tsimane' economy. Note that, given its connectedness with outsiders, the small group in the village is part of a network with nodes outside the village, so the measures of aggregate consumption adopted in Tables 5a and 5b might be misspecified for that group. However, as long as there are no exchanges taking place between Tsimane' and outsiders other than through financing, the finding of imperfect insurance in the small group should be robust because I have shown in the previous section that outsiders – unlike fellow villagers – do not provide insurance in the form of equity. This indicates that the degree of risk sharing in the small group is probably not underestimated.

This section has shown that there is potential underfunding of human capital with equity/insurance within villages, which would constitute a capital market imperfection. As equity is not available outside the villages, whoever demands such a contract runs the risk of not attaining equity but debt instead, which potentially leads to inefficient investment levels. Although their theoretical setting is not quite akin to the one in this paper, Banerjee and Newman (1998) predict migration, which also characterizes the most successful human capital investments in the Bolivian Amazon, at inefficient levels as a consequence of underinsurance outside the village network. As witnessed in Tables 2a and 2b, the small group is less invested in traditional assets, has higher income, and performs better on human capital measures. In order to scrutinize in what way these investment differences reflect the financial friction, one would want to relate investment decisions to the demand for debt and equity in this economy. Debt and equity contracts have different features that are appreciated by different borrower types: while debt provides full upside potential for the borrower, equity allows to give up some of the upside in order to gain partial downside protection. Given that the way cash flows are shared among borrowers and lenders distinguishes debt from equity, risk preferences are a likely (but not necessarily the unique) determinant of the demand for such contracts. Thus, one would expect the financial friction to matter for risk averse borrowers who would invest less in human capital if they were unable to attain equity/insurance.

Next, I present a model for the financing and investment problem of the villagers in this economy. The purpose of the model is twofold. First, it translates the above-described observations to testable hypotheses. Second, by relating contract demand to risk preferences, the model provides a parametric structure for eventual efficiency losses arising from the unavailability of equity contracts outside the villages.

4 Optimal Financing in a Two-Asset Problem

In this section, I attempt to formalize the decision problem of the villagers, and set up a model for the constituents of their investments in foraging-farming and human capital under optimal financing. I incorporate the choice of a financing contract in the investment decision of the borrowers, and yield a preference order for contracts based on the associated asset portfolios.

4.1 Model Setup

Tsimane' villagers face a simple portfolio problem: they can allocate time (denoted by $e \in [0,1]$) to foraging-farming and schooling. To finance this portfolio, they borrow the amount $I - W$ where I equals the fixed cost of investment and W denotes the borrower's internal funds (wealth). To simplify matters, I sketch a one-period decision problem. There are two assets in which the borrower can invest: I assume that foraging-farming yields a risk-free cash flow X^L at maturity, and human capital yields a cash flow of $X^H > 0$ with probability $p \in (0,1)$ and 0 otherwise. As discussed in Section 2.1.2, investment in human capital is riskier but yields higher cash flows. I therefore assume that $pX^H > X^L$. The borrower optimizes portfolio weights e and $1-e$ to maximize his expected utility. The marginal cost of investing in risky human capital is c and known to all parties.

I assume ex ante moral hazard over investment choice, so the portfolio weights are not contractible. The lender's payoff depends on state-contingent claims where a state is defined by a non-zero investment in one of the two asset classes. I assume that there is perfect competition among lenders. There are two types of lenders in this economy: a lender provides either extra-village debt or intra-village equity. Both lenders cannot observe e (moral hazard), but – depending on the contract that is written – they can observe the realized cash flows. That is, intra-village providers of equity have unconditional monitoring rights with respect to the borrowers' cash flow realizations whereas the monitoring rights of extra-village providers of debt are contingent (typically on bankruptcy). The contract offered by external lenders can be characterized as follows: $R^L = \min\left\{X^L, K^L\right\}$ and $R^H = \min\left\{X^H, K^H\right\}$ where K^L and K^H are determined by the lender (at a zero interest rate, K is simply the face value of debt). For the sake of simplicity, I assume $K^L = K^H$. Also, repayments must not decrease with cash flows, hence $R^L \leq R^H$. On the other hand, equity contracts can only be provided by intra-village lenders, and they demand $1-\delta$, $\delta \in [0,1]$, of the cash flows earned in every state.

In the remainder of this section, I solve for the borrower's optimal contract – and its associated weight on human capital – given all possible combinations of borrowers and lenders with regard to their risk preferences.

4.2 Risk Neutral Borrower

For the risk neutral borrower, I assume a quadratic cost function in e.

4.2.1 First Best (No External Funds Required)

Given the model setup, one can solve for the first best: the optimal portfolio weight on human capital e if the risk neutral borrower has sufficient internal funds to finance the investment $I - W$. The borrower solves:

$$\max\left\{W + epX^H + (1-e)X^L - \tfrac{ce^2}{2} - I\right\}$$

$$\Rightarrow e^*_{fb} = \tfrac{\Delta X}{c} \tag{7}$$

where $\Delta X \equiv pX^H - X^L$.

The optimal portfolio weight on human capital increases in the probability of success p, and decreases in the payoff to foraging-farming X^L and the marginal cost of investing in human capital c.

4.2.2 Borrower and Lender are Risk Neutral

If the borrower is not wealthy enough to self-finance the investment, he seeks outside finance. There are two financing contracts available in the economy (cf. Section 3.1). In the absence of any knowledge about the risk preferences of borrowers and lenders in- and outside the villages, I assume that the risk neutral borrower can freely choose between *extra-village debt* and *intra-village equity* from a risk neutral lender. I consider these two contracts separately.

Extra-village debt

$$\max\left\{W + pe^lR^H + (1-e^l)R^L + ep\left(X^H - R^H\right) + (1-e)\left(X^L - R^L\right) - \tfrac{ce^2}{2} - I\right\}$$

$$\Rightarrow e^*_d = \tfrac{\Delta X - \Delta R}{c} \tag{8}$$

where $\Delta X \equiv pX^H - X^L$, $\Delta R \equiv pR^H - R^L$, and e^l is the lender's expectation of e chosen by the borrower.

Comparing (8) to (7), one can see that the optimal portfolio weight on human capital is lower as long as $\Delta R > 0$, which is due to moral hazard involved in raising funds.

The lender has rational expectations, i.e., $e^l = e_d^*$, and – for zero profit – requires:

$$pe^l R^H + (1 - e^l)R^L = \Delta R \tfrac{\Delta X - \Delta R}{c} + R^L = I - W \tag{9}$$

This expression is maximized for $R^L = X^L$ and $\Delta R = \frac{\Delta X}{2}$, yielding the maximum amount $F_{extra}^{max} \equiv \frac{(\Delta X)^2}{4c} + X^L$.

Intra-village equity

$$\max \left\{ W + (1-\delta)pe^l X^H + (1-\delta)(1-e^l)X^L + \delta epX^H + \delta(1-e)X^L - \tfrac{ce^2}{2} - I \right\}$$

$$\Rightarrow e_e^* = \delta \tfrac{\Delta X}{c} \tag{10}$$

where $\Delta X \equiv pX^H - X^L$, e^l is the lender's expectation of e chosen by the borrower, and e_e^* is, again, lower than e_{fb}^*.

The lender has rational expectations, i.e., $e^l = e_e^*$, and breaks even:

$$(1-\delta)pe^l X^H + (1-\delta)(1-e^l)X^L = \delta(1-\delta)\tfrac{(\Delta X)^2}{c} + (1-\delta)X^L = I - W \tag{11}$$

Expression (11) implies a maximum borrowing amount $F_{intra}^{max} < F_{extra}^{max}$ because $\delta(1-\delta)$ is at most $\frac{1}{4}$ and $(1-\delta)X^L < X^L$. Interestingly, the borrower can raise more from outsiders than from fellow villagers as debt, rather than equity, is less information-sensitive (the payoff to the lender is proportional to the borrower's cash flows only in the case of default).

So far, I have only assumed that $W < I$. In the following, denote by F^{max} either F_{extra}^{max} or F_{intra}^{max} depending on whether one considers debt or equity. One has to differentiate between three cases for values of W:

1. $F^{max} < I - W \Leftrightarrow W < I - F^{max}$

2. $I - X^L > W \geq I - F^{max}$

3. $I - W \leq X^L \Leftrightarrow W \geq I - X^L$

Case 1 implies no investment, and any contract is feasible in Case 3. Hence, one is left with Case 2. From this, one knows that $R^L = X^L$ because raised funds will not be sufficient otherwise. I also impose the following technical assumption to yield a real solution:

A1 $\frac{(\Delta X)^2}{c} \geq \max\left\{4(I - W - X^L), X^L\right\} \Rightarrow \left(\Delta X - \frac{X^L c}{\Delta X}\right)^2 \geq 4c\left(I - W - X^L\right)$

I now present the borrower's optimal contract in Proposition 1, with the respective proof in the Appendix.

Proposition 1 *Under A1, if the borrower and the lender are risk neutral, the borrower prefers debt to equity. The corresponding debt contract is given by*
$K = \frac{1}{2}\left(pX^H + X^L\right) - \frac{1}{2}\sqrt{(\Delta X)^2 - 4c\left(I - W - X^L\right)}.$

Given the borrower's risk neutrality and the assumption that human capital has a higher expected return than foraging-farming, the borrower's utility is increasing in the portfolio weight on human capital. Thus, the optimality of debt implies $e_e^* < e_d^*$.

4.2.3 Risk Neutral Borrower and Risk Averse Lender

For the case of risk aversion on the part of the lender, I impose an additional assumption on the nature of the cash flows:

A2 $X^L > \frac{\Delta X}{2}$

This assumption should not be of concern as it imposes a generous upper bound on the spread in expected payoffs between human capital and foraging-farming. As I have already discussed in Section 2.1.2, the data suggest that $X^H - X^L \approx X^L$ which is, even without discounting X^H by p, clearly less than $2X^L$. With A2, the following proposition can be understood as a corollary of Proposition 1 (again, the proof is in the Appendix).

Proposition 2 *Under A1 and A2, if the borrower is risk neutral, he prefers debt to equity (irrespective of the lender's risk preferences).*

Just like in the previous case, the optimality of debt implies $e_e^* < e_d^*$. Finding conditions under which a risk neutral borrower's preference for debt is independent of the lender's type (as defined by his risk preferences) is useful insofar as one can more easily test the proposition in the data without controlling for lender risk preferences. To this end, an analogous result is presented for the case of the risk averse borrower in the next section.

4.3 Risk Averse Borrower

This subsection analyzes the case of the risk averse borrower in a similar fashion as the previous one. For purely algebraic reasons, I assume that the borrower has a simple CARA utility function $U(x) = -\exp(-x)$, alongside a linear cost function.

4.3.1 First Best (No External Funds Required)

The borrower solves the following problem:

$$\max \left\{ \begin{array}{c} -p\exp\left(-\left(W + eX^H + (1-e)X^L - ce - I\right)\right) \\ -(1-p)\exp\left(-\left(W + (1-e)X^L - ce - I\right)\right) \end{array} \right\}$$

$$\Rightarrow e_{fb}^* = \frac{\ln\left(\frac{p}{1-p}\frac{\Delta\widetilde{X}-c}{X^L+c}\right)}{X^H} \tag{12}$$

where $\Delta\widetilde{X} \equiv X^H - X^L$.

As in the case of the risk neutral borrower, the optimal portfolio weight on human capital increases in the probability of success p, and decreases in the payoff to foraging-farming X^L and the marginal cost of investing in human capital c.

4.3.2 Risk Averse Borrower and Risk Neutral Lender

I present the borrower's problem separately for debt and equity. Note that I have already inserted $pe^lR^H + (1-e^l)R^L = (1-\delta)pe^lX^H + (1-\delta)(1-e^l)X^L = I - W$, and that $X^L = R^L$ as seen in the previous analysis.

Extra-village debt

$$\max\left\{\begin{array}{c}-p\exp\left(-\left(e\left(X^H-R^H\right)+(1-e)\left(X^L-R^L\right)-ce\right)\right)\\-(1-p)\exp\left(-\left((1-e)\left(X^L-R^L\right)-ce\right)\right)\end{array}\right\}$$

$$\Rightarrow e_d^*=\frac{\ln\left(\frac{p}{1-p}\frac{\Delta\widetilde{X}-\Delta\widetilde{R}-c}{c}\right)}{\Delta\widetilde{X}-\Delta\widetilde{R}} \tag{13}$$

where $\Delta\widetilde{X}\equiv X^H-X^L$, $\Delta\widetilde{R}\equiv R^H-R^L$, and $\Delta\widetilde{X}-\Delta\widetilde{R}=X^H-R^H$ because $X^L=R^L$.

Intra-village equity

$$\max\left\{\begin{array}{c}-p\exp\left(-\left(\delta eX^H+\delta(1-e)X^L-ce\right)\right)\\-(1-p)\exp\left(-\left(\delta(1-e)X^L-ce\right)\right)\end{array}\right\}$$

$$\Rightarrow e_e^*=\frac{\ln\left(\frac{p}{1-p}\frac{\delta\Delta\widetilde{X}-c}{\delta X^L+c}\right)}{\delta X^H} \tag{14}$$

where $\Delta\widetilde{X}\equiv X^H-X^L$.

The risk neutral lender has rational expectations and breaks even, i.e., $pe_d^*R^H+(1-e_d^*)R^L=(1-\delta)pe_e^*X^H+(1-\delta)(1-e_e^*)X^L=I-W$.

As in the case of Proposition 2, I impose assumptions on the cash flow structure:

A3 $pX^H-X^L>\frac{c}{p}$

A4 $\frac{p\left(\Delta\widetilde{X}-c\right)}{X^L+c}\leq\frac{(1-p)c}{pX^H-X^L}$

At the minimum, A3 is not restrictive in the sense that one requires $pX^H-X^L>c$ anyways to yield a valid portfolio weight in the first-best case e_{fb}^* (cf. equation 12), and p is found to be at least 0.8 in the data. I now state the proposition whose proof can be found in the Appendix:

Proposition 3 *Under A3 and A4, if the borrower is risk averse and the lender is risk neutral, the borrower prefers equity to debt.*

The proof shows that, due to the borrower's risk aversion, the optimality of equity implies $e_d^*<e_e^*$.

4.3.3 Borrower and Lender are Risk Averse

Now the lender is also risk averse. Similarly to the relationship between Propositions 1 and 2, Proposition 4 can be understood as a corollary of Proposition 3 (for the proof, see Appendix).

Proposition 4 *Under A3 and A4, if the borrower is risk averse, he prefers equity to debt (irrespective of the lender's risk preferences).*

Again, the optimality of equity implies $e_d^* < e_e^*$. Overall, I have shown that, if the borrower is risk averse, he prefers equity to debt. Furthermore, as can be seen by comparing (8) to (13) and (10) to (14), a risk averse borrower invests less in human capital than in the case of risk neutrality, and even more likely so the higher his degree of risk aversion.

5 Empirical Evidence of the Relationship between Financing Contracts and Human Capital Investment

Tables 2a and 2b present two frontal facts about the differences between the small and the large group: the small group is less invested in foraging-farming and more invested in human capital, and yields a higher average income than the large group. Furthermore, the small group showcases a higher degree of connectedness, particularly with outsiders. The investment profiles of the groups could readily be reconciled with this characterization of the groups.

However, there exists an alternative explanation for investment differences between the two groups. In order to invest in foraging-farming and schooling, many villagers borrow money from external resources. As seen in Section 3.1, the type of financing contract offered depends on the relationship between borrowers and lenders such that equity-like contracts, as an alternative to more standard debt contracts, are only offered in- but not outside the villages. Furthermore, there is underfunding of human capital with equity/insurance. Thus, villagers demanding equity potentially cannot attain the contract, which eventually leads them to invest less in human capital than they would actually prefer to. In this section, I scrutinize in what way different demand for contracts in the two groups can explain the earnings gap through underinvestment in human capital.

5.1 Testing the General Model for Human Capital Investment

I first test the general model for the equilibrium portfolio weight on human capital investment (see e^* in equations 8 and 10 for the risk neutral case, and equations 13 and 14 for the risk averse case). In particular, I make two assumptions about the information structure in the borrower-lender relationship. First, monitoring rights with respect to the borrower's cash flow realization matter insofar as the payoff structure for the lender is more information-sensitive under an equity contract than under debt. The immediate consequence is that $F_{intra}^{max} < F_{extra}^{max}$, and, indeed, the mean yearly borrowings in the data are 236.74 (with a standard deviation of 548.08) under extra-village debt compared to 113.81 (with a standard deviation of 352.71) under intra-village equity (the difference is significant at the 1% level).

Second, and most importantly, the only reason why the optimal portfolio weight e^* is not first-best and thus varies with the type of financing is moral hazard. The equilibrium portfolio weight on human capital investment is lower than in the first-best scenario because of moral hazard involved in raising funds.

I now test the model prediction for the equilibrium portfolio weight on human capital. As demonstrated in Section 4, the optimal portfolio weight on human capital typically increases in the probability of success p, and decreases in the payoff to foraging-farming X^L as well as the marginal cost of human capital investment c. Under the assumption that more time investment in human capital leads to improved human capital outcomes, I define the dependent variable $Marginal\ human\ capital\ investment_{it} \in \{0, 1\}$ as an indicator whether i's Spanish speaking and/or reading skills improved since $t-1$. As a proxy for p, I use a dummy variable which indicates whether any people left i's village between $t-1$ and t to move to San Borja, which is a sufficient indicator for their having found a job. Furthermore, I approximate the inverse of the payoff to foraging-farming $1/X^L$ by the inverse of the village selling price of a one-year old pig. Last, I use the ratio between villager i's math test score in $t-1$ to years of education $Ability_{i,t-1}$ as a proxy for i's learning productivity and thus for the inverse of c – note that I choose the lagged value to avoid simultaneity with *Marginal* *human capital investment*$_{it}$.[9]

[Insert Table 6a about here]

[Insert Table 6b about here]

In the first two columns of Tables 6a and 6b, one can see that all three variables generally have the predicted positive sign. Now I include changes in money borrowings by defining $\Delta Leverage\ ratio_{it}$ as the log change of i's net total borrowings over bi-weekly earnings from sales of goods, wage labor, and barter. I weight changes in leverage by changes in income in order to account for repayment ability. If funds need to be raised, the marginal benefit of investing in human capital drops, and so do the positive sensitivities to p, $1/X^L$, and $1/c$. Thus, a test of second-best investment in human capital implies that, in the presence of leverage, the positive impact of the regressors in the first two columns of Tables 6a and 6b is reduced. That is, the respective interaction effects with $\Delta Leverage\ ratio_{it}$ should all be negative. Indeed, in the last two columns of Tables 6a and 6b, the signs are negative (and almost always significant).

There is, however, a caveat attached to these estimations as they do not account for the potentially endogenous nature of $\Delta Leverage\ ratio_{it}$.[10] This reflects the assumption that receiving funds is not generally endogenous in a society as reciprocal as that of the Tsimane'. Rather, receiving a specific contract (extra-village debt or intra-village equity) is endogenous, for which I will account in the following section.

5.2 Allocation of Contracts and its Impact on Human Capital Investment

Having empirically verified the basic features of the model in Section 4, I finally test the impact of financing contract choice on human capital investment. The respective coefficient

[9] On a more general note, one might worry that serial correlation emerges in a setup which involves lagged variables on the right-hand side that might partially be a function of the dependent variable. However, serial correlation is unlikely to impact my results as the Baltagi-Wu locally best invariant (LBI) test statistic is greater than 2 in all specifications involving lagged variables, implying that, if anything, standard errors are likely to be overestimated.

[10] For instance, it is reasonable to assume that Tsimane' with good Spanish skills are more likely to receive funds from cattle ranchers. In that case, the positive coefficient of $\Delta Leverage\ ratio_{it}$ is an underestimate because Tsimane' with good Spanish skills are less likely to *further increase* their fluency.

is endogenous to the borrower's risk preferences as the more risk averse types prefer equity to debt. Furthermore, there is potential underfunding of human capital with equity, and equity is only available in- but not outside the villages. Thus, whenever equity is not attainable, debt is used. This market imperfection potentially leads to underinvestment in human capital whenever borrowers who prefer equity were to receive debt instead. As seen in Section 4, the type of borrower that would underinvest in human capital upon receiving debt rather than equity/insurance is more risk averse.

Table 4 already indicates that the most capable members, i.e., the ones who ought to be most likely to receive their preferred financing contract,[11] of the large group receive equity whereas their counterparts in the small group receive debt. If the differential demand for contracts is driven by differences in risk attitudes, without controlling for the underlying endogeneity, one should find a (more) negative coefficient of the usage of equity contracts on marginal human capital investment.

However, the impact of equity is understated for it fails to reflect its optimality for risk averse borrowers who would underinvest in human capital if they were to receive debt instead. Hence, once the endogeneity at hand is accounted for by randomizing contracts over the population, some of the villagers who received debt, rather than equity, are shown to be more risk averse if the respective coefficient on equity increases. On the other hand, upon randomization of debt, the coefficient on the latter should – if anything – drop because no one who did not receive debt would have wanted it in the first place (the market for debt is not imperfect). That is, someone who did not borrow any money and would thus be likely to invest the first-best level in human capital would underinvest under a debt contract, and so would a villager who (is more risk averse and therefore) prefers equity/insurance.

To test these conjectures, I refine the specification used in Table 6a by including an

[11] Given that the villages are very small (cf. Table 1), it is reasonable to reconsider the assumption of hidden information made so far, as reflected by contingent monitoring rights between villagers and outsiders in the design of financing contracts. Unlike cash flow monitoring, the initial screening of borrowers is not costly in a dense village setting, irrespective of lender affiliation, which is why c is assumed to be public information in the model of Section 4. A similar idea is reinforced by the findings in Table 3c as outside lenders turn out to be at least as good at screening borrowers as fellow villagers. Lenders can thus choose to serve the most capable borrowers first, and the most capable borrowers are more likely to receive their preferred contract. This implies that lenders are not necessarily operating under perfect competition, but rather have some positive reservation utility $\bar{u}$. If one assumes that $\bar{u}$ is the same for all lenders, the propositions in Section 4 still hold.

indicator for financing contract choice:[12] *Majority funds from villager*$_{it} \in \{0,1\}$ is zero if no funds were raised, and is one if i borrowed the majority of his funds in intra-village equity (i.e., *Proportion Funds Borrowed from Villager*$_{it} > 0.5$, cf. Table 4). Similarly, *Majority funds from outside*$_{it} \in \{0,1\}$ is zero if no funds were raised, and is one if i borrowed the majority of his funds in extra-village debt. These two indicator variables span the (three-dimensional) state space for potential borrowers: if both variables are zero, the villager is in the first-best case where no funds are required, and he is in either the equity or the debt case if the respective indicator is equal to one.

In order to account for the endogeneity of financing contracts, i.e., contract preferences, I employ an instrumental variables approach. For both *Majority funds from villager*$_{it}$ and *Majority funds from outside*$_{it}$, I will use one instrument, and show the robustness of the results to an alternative choice for the instrument. First, as can be inferred from Table 4, *Member of large group*$_i \times$ *Ability*$_{i,t-1}$ is highly correlated with a villager's decision to borrow from a fellow villager rather than an outsider. To use this interaction as an instrument for actual contract choices, I assume that group-specific learning productivity *Member of large group*$_i \times$ *Ability*$_{i,t-1}$ does not impact human capital outcomes conditional on *Member of large group*$_i$ and *Ability*$_{i,t-1}$ which are controlled for in the second stage. That is, the most capable members of the two groups are assumed to differ in their preferences for financing contracts, but not in their marginal human capital investments. The data back up the assumption that learning productivity does not lead to greater improvements in Spanish fluency for any one of the two groups: the Spanish gap in Tables 2a and 2b does not vary irrespective of whether one considers villagers with high or low learning productivity *Ability*$_{i,t-1}$.

As an alternative instrument, I use the average *Cost of divorce shocks*$_{vt}$ in a village as a determinant of potential lenders' budget constraints in- but not outside the villages (i.e., a shock to the supply of funds in a village), which is orthogonal to individual human capital shocks.

[Insert Table 7a about here]

[Insert Table 7b about here]

[12] As seen in Tables 6a and 6b, the linear probability and probit models do not yield qualitatively different results. Thus, I will use linear specifications in the remaining analysis.

[Insert Table 7c about here]

The results of the first-stage linear probability model are presented in Table 7a, and support the validity of the instruments. Reminiscent of Table 4, the most capable members of the large group opt for intra-village equity whereas the most capable members of the small group receive extra-village debt. Although the latter effect is not statistically significant, the first stage still has sound explanatory power as the least capable members of the large group attain debt, which is another sign that underfunding with equity might indeed be at play. Furthermore, the alternative instrument, a shock to the lenders' budget constraints in the village, is highly correlated with the contracts in that it decreases the likelihood of receiving intra-village equity and increases that of receiving extra-village debt.

The second stage explains $\textit{Marginal human capital investment}_{it}$ just like the specification in Table 6a, augmented by $\textit{Member of large group}_i$ and $\textit{Ability}_{i,t-1}$. The results are displayed in Table 7b, with and without controlling for endogeneity. The ordinary least squares estimates are indicative of the borrowers' risk preferences: the villagers in the large group who – according to the first stage in Table 7a – prefer equity invest less in human capital and are thus more risk averse than villagers who either prefer debt or do not require any funding at all. Note that the negativity of the coefficient on $\textit{Majority funds from villager}_{it}$ remains even if one includes $\textit{Majority funds from outside}_{it}$, which is not significant, in the same regression (unreported in this paper) and leaves the first-best case (no funding required) as the baseline. It is furthermore noteworthy that the intercept effect $\textit{Member of large group}_i$ is insignificant throughout all estimations in Table 7b. Lastly, estimates from the reduced form for $\textit{Marginal human capital investment}_{it}$ can be found in Table 7c, and confirm the differential impact of the two instruments on human capital outcomes.

Two-stage least squares estimates reveal that the impact of equity on marginal human capital investment is understated whereas that of debt is, if anything, overstated if one does not control for endogeneity. For the sign switching of the equity coefficient, the underlying rationale is that a subset of villagers who received debt would have invested more in human capital if they had been able to attain equity/insurance – I interpret this as a sign of their risk aversion. From the first stage, one knows that the group that is more likely to fall in this category is the large group. Therefore, potential underfunding with equity influences allocative efficiency, and risk averse villagers in the large (inward-looking) group are likely affected by this financial friction.

With risk preferences in hand, I next quantify the efficiency loss in the large group, that is the underinvestment in human capital due to the restricted availability of equity contracts.

6 A Counterfactual Analysis of Human Capital Investment and Imperfect Capital Markets

In Section 5.2, I infer the risk preferences in the two groups from the relationship between financing contracts and human capital investment. By doing so, I find that the large group prefers equity to debt, and should on average be more risk averse than the small group. The human capital gap witnessed in Tables 2a and 2b could therefore be due to risk aversion. Yet, the extent to which risk preferences alone can explain the human capital gap depends on how (im)perfect the capital market in the economy is. While the members of the small group receive debt which is readily provided at least by outsiders, more risk averse villagers in the large group demand equity which can only be attained in their villages. Albeit optimal for risk averse villagers to invest less in human capital, they do not necessarily receive a contract that allows them to invest efficiently in human capital.

There is also a second layer of efficiency loss: given that there is assortative mating among three-quarters of the population in the villages, one might be led to believe that the members of the large group are risk averse with very little intra-group heterogeneity if that trait were to be intergenerationally transmitted (Dohmen et al., forthcoming).[13] Thus, one has that most of the eligible lenders of equity/insurance are risk averse, but risk averse lenders are typically not the best providers of equity.

In this section, I explore the welfare implications of the capital market imperfection that equity can only be written within villages, which reinforces the problem of underfunding of human capital, and present a counterfactual analysis of human capital investment for the risk averse group in the large (inward-looking) group. As some of the risk averse borrowers

[13] Attanasio et al. (2009) provide further evidence of assortative matching with respect to risk preferences in social networks.

might not be served with equity, they have to enter debt contracts with lenders outside their villages. However, debt is suboptimal for risk averse borrowers, leading them to invest less in human capital than they would want to. In a perfect capital market, risk averse borrowers would be able to attain equity everywhere, i.e., also from lenders outside their network.[14] In order to compute a counterfactual human capital portfolio weight for the members of the large group, I calibrate the optimal portfolio weight on human capital investment e^* from the model in Section 4.

6.1 Procedure and Parameters

As seen in Section 4, the equilibrium portfolio weight on human capital investment is a function of the borrower's risk preferences and the contract type. Given the equity availability constraint, risk averse villagers receive no equity (but only debt) from outsiders which I assume to be risk neutral. In a perfect capital market, this constraint will be relaxed. Hence, in the actual state of the economy, risk averse borrowers can either receive equity from fellow villagers (the majority of which is also risk averse) or debt from risk neutral outside lenders. Denote the respective human capital portfolio weights and population densities by e_{aa}^{equity}, e_{an}^{debt}, θ_{aa}, and θ_{an} where a stands for risk aversion, n indicates risk neutrality, and the first and second indices correspond to the borrower's and lender's risk preferences, respectively. Then, the average investment in human capital by risk averse borrowers equals:

$$e = \theta_{aa} e_{aa}^{equity} + \theta_{an} e_{an}^{debt} \tag{15}$$

In a perfect capital market, risk averse borrowers attain equity from risk neutral lenders. Hence, the counterfactual investment in human capital is equal to:

$$\widetilde{e} = \theta_{aa} e_{aa}^{equity} + \theta_{an} e_{an}^{equity} \tag{16}$$

Based on (15) and (16), one can compute a counterfactual human capital investment rate $\widetilde{e}$ and the corresponding difference $\widetilde{e} - e$ which one can interpret as the normalized increase in the risk averse villagers' efforts towards schooling rather than foraging-farming. Note

[14]Note that risk neutral borrowers prefer debt, and can attain it irrespective of the lender type, so their human capital investment level would not change in a perfect capital market.

that, for the difference $\widetilde{e} - e$, it does not matter that I have assumed that borrowers and lenders from the same village are both risk averse and always enter equity rather than debt arrangements with one another.[15]

There are two matches: aa and an, and a risk averse villager $i \in \{aa, an\}$ is assigned to the lender from whom he receives the majority of his funds. The two relevant human capital portfolio weights – e_{an}^{debt} and e_{an}^{equity} – are averages for the respective matches, and calibrated as follows. First, I calibrate the portfolio weights for two types of utility specifications, CARA and CRRA utility. Then, based on bi-weekly data, one has $X^H \approx 2X^L$, and – as seen in Section 2.1.2 – the empirical likelihood of zero income turns out to be 14.91% lower for foraging-farming than for wages upon schooling, so one can interpret p to be at most 0.85. To be somewhat conservative, I use $p = 0.8$.

Furthermore, I assume the marginal cost of investing in human capital to be heterogeneous:[16]

$$c_i = \alpha - \beta Ability_i \tag{17}$$

where $Ability_i$ is equal to the first observation of $Ability_{it}$, the ratio of i's math score to years of schooling.

Also, as seen in Section 4, I assume that $I - W > X^L$. Based on these assumptions, I calibrate the parameters such that the equilibrium portfolio weight on human capital is between zero and one. Note that this constraint leads to a wider range of admissible values for β in the case of CARA. Table 8 lists all baseline parameters.[17]

[Insert Table 8 about here]

The population densities are drawn from the data which comprise the subset of all villagers ($N = 478$) who borrow money in any given year (see Table 2b for the descriptive statistics). Most importantly, the fact that θ_{an} is not zero but rather large demonstrates that many risk

[15] As seen in Tables 3a and 3b, debt is likely also available within villages.

[16] For sheer computational reasons, I use a linear cost function ce, rather than a quadratic cost function, for the CARA utility specification.

[17] In the case of CARA, A3 in Proposition 3 might not be fulfilled. As can be seen in the proof of Proposition 3, the conjecture goes through as long as $p\frac{pX^H - X^L}{c + pX^L - p^2X^H} + X^L < I - W$ which holds for the parameters in Table 8.

averse borrowers cannot receive their optimal contract, and are forced to raise debt from outside the village. As I drop the assumption of hidden information with respect to borrower screening, it is likely that risk averse borrowers of debt are deemed to be less capable, as suggested by Table 7a. Yet, while in the current state of the economy less able risk averse villagers receive funds from outside and the most capable ones receive funds from inside the village, the opposite should hold in the counterfactual scenario. This is because, given that equity investments are more volatile than debt investments, the best possible provider of equity is typically as little risk averse as possible. In order to conservatively account for the re-allocation of talent in the counterfactual scenario, I also compute (16) using the average cost c for all risk averse borrowers:

$$c = \frac{1}{n}\sum_{i=1}^{n} c_i = \alpha - \frac{\beta}{n}\sum_{i=1}^{n} Ability_i \tag{18}$$

In summary, given a utility specification (either CARA or CRRA), I will present two major categories of results for the calibrated human capital increase $\widetilde{e}-e$: with and without average cost adjustment in the counterfactual scenario (cf. (16)). Within each of these categories, I vary β, the sensitivity of the marginal cost of human capital investment to $Ability_i$ in (17) and (18). I now turn to the results and a discussion of the role of a perfect capital market in closing the earnings gap between the two groups.

6.2 Discussion of Results

I first compute the counterfactual increase in human capital investment $\widetilde{e}-e$ taking as given the population densities of the matches between borrower and lender types from Table 8. The results for CARA and CRRA utility are presented in Tables 9 and 10, respectively. I also present the pure counterfactual increase in human capital (i.e., if $\theta_{an} = 1$).

[Insert Table 9 about here]

[Insert Table 10 about here]

Without average cost adjustment (cf. first panel of Tables 9 and 10), the results are robust to variations in β: the counterfactual increase in human capital investment is roughly

0.33 for CARA and 0.15 for CRRA utility. The results with average cost adjustment (cf. second panel of Tables 9 and 10) are, as expected, slightly higher: up to 0.34 for CARA and 0.17 for CRRA utility. From this, one can infer the explanatory power of an imperfect capital market for the earnings gap between the two groups, as given in Table 2b. The gap in bi-weekly income is approximately equal to 30 bolivianos. The spread in expected payoffs between human capital and foraging-farming, $pX^H - X^L$, measured on a bi-weekly basis is about 60 bolivianos $(0.8 \times 200 - 100)$. In order to explain the entire earnings gap through underinvestment in human capital, $\widetilde{e} - e$ would have to be equal to $\frac{30}{60} = 0.5$. At the sight of the calibration results, one can conclude that the efficiency loss in terms of underinvestment in human capital are sizable, and can explain a substantial portion of the actual earnings gap in the data. In the case of CRRA utility, that portion amounts to at least 30% of the earnings gap between the two groups.

7 Concluding Remarks

This paper analyzes a very simple economy in a hunter-gatherer society in Amazonian Bolivia, and attempts to shed light on the relationship between social networks and investment decisions. Villagers who are not fully invested in foraging-farming can attend school to study Spanish and eventually find employment in logging camps, on cattle ranches, and farms of colonist farmers. In order to finance these investments, funds can be raised from fellow villagers and lenders outside the village. While the standard contract can be characterized as debt, insurance in the form of equity – i.e., borrowings the repayment of which is proportional to the debtor's income – is only available within villages. However, fellow villagers underfund human capital with equity/insurance, leading to a general lack of insurance of human capital investments in the economy. I have shown that this financial friction potentially matters for the vast majority of villagers who consequently underinvest in human capital.

This economy features an exogenous network boundary which is based on mating norms and splits each village into two groups. Given their differential demand for equity/insurance, I have come to explain a substantial portion of a human capital gap between the two groups through the financial friction. If one is to understand by that financial friction the limited willingness to finance human capital investments in village networks, forcing some potential borrowers to seek financing outside their villages where insurance is unavailable, then the resulting human capital gap is a testimony of the cost incurred by those who are more dependent on networks. This reflects a generalizable downside of networks, and warrants a more sober assessment of the net benefits of certain network structures for economic growth.

The type of intra-village heterogeneity considered in this paper is based on risk preferences. The two mating groups differ in their degree of connectedness, particularly outside the village, and I infer that the outward-looking group makes investment and financing decisions that are consistent with a lower degree of risk aversion. This implies an inverse relationship between risk aversion and openness/proximity to markets. A similar relationship is thought to hold true even in modern societies, e.g., a positive correlation between risk neutrality and market completeness (Palacios-Huerta and Santos, 2004). Yet, the behavior of the hunter-gatherers, who have only recently been exposed to a market economy, suggests reverse causality: maybe risk attitudes can influence individual willingness to engage more fully in markets, rather than market exposure forming risk attitudes. While such a perspective would be subject to further debate, it exemplifies the possibly wide-ranging merits of studying hunter-gatherers, and the relevance of simplistic social and economic arrangements for counterfactual analyses of more complex institutional structures.

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Appendix

Tables

Table 1: Proportion of Households Practicing Cross-Cousin Marriage

Village	Average proportion from 2002-2006	# of observations
Village 1	0.351	111
Village 2	0.538	132
Village 3	0.733	101
Village 4	0.433	60
Village 5	0.682	107
Village 6	0.865	52
Village 7	0.859	64
Village 8	0.980	51
Village 9	0.973	73
Village 10	0.918	122
Village 11	0.737	38
Village 12	0.837	123
Village 13	0.724	98
Village 14 (only 2005-2006)	0.917	12
All villages	0.718	1,088

Notes: A household is defined as practicing cross-cousin marriage if more than half of the household members report that marrying anyone but a cross cousin is unacceptable. Households typically unanimously agree on mating norms, and the fraction of households with a perfectly split opinion on the matter is roughly one eighth.
Given the size of the group of villagers practicing cross-cousin marriage, I label the latter as the "large group" (and the remaining group as the "small group") in the economy.

Table 2a: Descriptive Statistics (Total Sample)

Variable	Small group Mean [Std. dev.]	N	Large group Mean [Std. dev.]	N	p-value
Income (in bolivianos in two weeks)	152.94 [595.02]	212	91.79 [117.75]	600	0.017
Income (no barter, in bolivianos in two weeks)	144.33 [594.43]	212	84.23 [114.72]	600	0.019
Bi-weekly wage per hour (productivity under wage labor)	28.82 [22.19]	93	26.14 [7.77]	245	0.100
Consumption per household (in bolivianos in a week)	161.40 [80.83]	76	162.73 [88.42]	192	0.910
Total assets (in bolivianos)	3527.15 [2089.97]	502	3501.18 [2178.71]	1,336	0.818
Traditional assets (in bolivianos)	690.33 [367.54]	502	813.37 [447.37]	1,336	0.000
Asset borrowings (in days per week)	0.26 [0.38]	212	0.27 [0.36]	598	0.938
Credit (in bolivianos in a week)	5.07 [18.33]	212	3.64 [15.51]	600	0.272
Currently in school	0.31 [0.40]	458	0.29 [0.38]	1,268	0.214
Years of schooling (latest available)	1.81 [2.18]	381	1.64 [2.02]	963	0.180
Math score (0-4)	0.84 [1.27]	385	0.77 [1.21]	1,045	0.311
Math score / Years of schooling	0.29 [0.53]	386	0.26 [0.41]	1,046	0.226
Spanish reading (0-2)	0.42 [0.72]	385	0.41 [0.71]	1,045	0.652
Spanish speaking (0-2)	0.75 [0.78]	388	0.59 [0.70]	1,047	0.000
Household size (in 2006)	6.58 [2.83]	76	6.21 [2.88]	193	0.401

Notes (Tables 2a and 2b): All means and standard deviations are calculated based on averages of individuals. The third column indicates the p-value of a two-sided difference-in-means test where */**/*** denote significance at the 10%/5%/1% level, respectively.

Table 2b: Descriptive Statistics (Calibration Sample)

	Small group		Large group		
Variable	Mean [Std. dev.]	N	Mean [Std. dev.]	N	p-value
Income (in bolivianos in two weeks)	145.46 [171.41]	115	115.70 [130.65]	363	0.050
Income (no barter, in bolivianos in two weeks)	136.32 [167.27]	115	105.57 [127.65]	363	0.038
Bi-weekly wage per hour (productivity under wage labor)	30.24 [24.38]	65	26.91 [7.54]	181	0.103
Consumption per household (in bolivianos in a week)	170.92 [72.09]	68	160.67 [84.26]	177	0.377
Total assets (in bolivianos)	3274.48 [1963.52]	115	3564.51 [2255.25]	363	0.216
Traditional assets (in bolivianos)	654.07 [336.75]	115	850.85 [462.58]	363	0.000
Asset borrowings (in days per week)	0.29 [0.38]	115	0.32 [0.37]	363	0.453
Credit (in bolivianos in a week)	9.15 [24.15]	115	6.00 [19.59]	363	0.157
Currently in school	0.20 [0.30]	114	0.20 [0.32]	361	0.949
Years of schooling (latest available)	2.42 [2.82]	121	2.24 [2.54]	331	0.506
Math score (0-4)	1.29 [1.50]	115	1.15 [1.47]	362	0.364
Math score / Years of schooling	0.36 [0.50]	115	0.34 [0.43]	363	0.678
Spanish reading (0-2)	0.74 [0.86]	115	0.65 [0.85]	362	0.335
Spanish speaking (0-2)	1.17 [0.75]	115	1.00 [0.74]	362	0.031
Household size (in 2006)	6.62 [2.77]	55	6.50 [2.90]	143	0.789

Table 3a: Repayment Increases with Borrower's Income Only in Villages
(Equity in Villages, Debt Outside)

	Dependent variable: $\max\{0, -\Delta Total\ borrowings_{it}\}$		
$Borrowed\ from\ villager_{i,t-1}$	-3.295		4.805
	[28.58]		[27.86]
$Borrowed\ from\ outside_{i,t-1}$		35.838***	44.800***
		[16.76]	[12.54]
$Gross\ income_{i,t-1}$	0.033	0.008	-0.015
	[0.04]	[0.02]	[0.02]
$Borrowed\ from\ villager_{i,t-1}$	0.375**		0.341**
$\times\ Gross\ income_{i,t-1}$	[0.18]		[0.17]
$Borrowed\ from\ outside_{i,t-1}$		0.159	0.089
$\times\ Gross\ income_{i,t-1}$		[0.11]	[0.06]
Fixed effects	Individual	Individual	Individual
# of observations	1,552	1,552	1,552
# of individuals	662	662	662

Notes (Tables 3a and 3b): */**/*** denote significance at the 10%/5%/1% level, respectively. In the (individual) fixed effects regressions, standard errors are clustered at the household level. Controls for the following idiosyncratic shocks at time t are included: animal loss, crop loss, family death, fire, flood, health, theft, divorce, and "other." $\Delta Total\ borrowings_{it}$ denotes the absolute change in total borrowings over one year. $Borrowed\ from\ villager_{it}$ and $Borrowed\ from\ outside_{it}$ are indicator variables for whether i borrowed any money from in- or outside the Tsimane' community during the 54 weeks before year t. $Gross\ income_{it}$ is equal to earnings from sales of goods, wage labor, and barter over the last two weeks in year t, plus the average consumption per household member of game, fish, eggs, maize, manioc, rice, oil, and bread (in bolivianos) in the last week of year t.

Table 3b: Repayment Increases with Borrower's Income Only in Villages
(Equity in Villages, Debt Outside)

	Dependent variable: $\max\{0, -\Delta Total\ borrowings_{it}\}$		
$Borrowed\ from\ villager\ before_{i,t-1}$	8.092		8.111
	[31.20]		[30.59]
$Borrowed\ from\ outside\ before_{i,t-1}$		25.312*	27.991***
		[13.59]	[10.54]
$Gross\ income_{i,t-1}$	0.031	0.013	-0.030
	[0.04]	[0.03]	[0.03]
$Borrowed\ from\ villager\ before_{i,t-1}$	0.314*		0.304*
$\times\ Gross\ income_{i,t-1}$	[0.17]		[0.17]
$Borrowed\ from\ outside\ before_{i,t-1}$		0.113	0.076
$\times\ Gross\ income_{i,t-1}$		[0.09]	[0.05]
Fixed effects	Individual	Individual	Individual
# of observations	1,552	1,552	1,552
# of individuals	662	662	662

Notes: $Borrowed\ from\ villager\ before_{i,t-1}$ and $Borrowed\ from\ outside\ before_{i,t-1}$ are indicator variables for whether i borrowed any money from in- or outside the Tsimane' community during the 108 weeks before year t. Or, put differently: $x_{it} \equiv Borrowed\ from\ y\ before_{it}$, $y \in \{villager, outside\}$, is given by $x_{it} = \max\{x_{ij}\}_{j \geq t-1}$.

Table 3c: Have Successful Borrowers Received More Funds from In- or Outside the Village?

	Borrowed from $villager_{i,t-1} = 1$		*Borrowed from* $outside_{i,t-1} = 1$	
$Income\ percentile_{it}$	Top 20%	Bottom 80%	Top 20%	Bottom 80%
$Total\ borrowings_{i,t-1}$	163.66 [345.42]	110.02 [404.70]	251.44 [496.18]	136.49 [402.61]
# of observations	65	201	183	541
$Income\ percentile_{it}$	Top 50%	Bottom 50%	Top 50%	Bottom 50%
$Total\ borrowings_{i,t-1}$	128.16 [280.83]	118.02 [478.85]	201.13 [427.65]	132.61 [431.55]
# of observations	134	132	348	376

Notes: $Borrowed\ from\ villager_{it}$ and $Borrowed\ from\ outside_{it}$ are indicator variables for whether i borrowed any money from in- or outside the Tsimane' community during the 54 weeks before year t. $Total\ borrowings_{it}$ denotes the total amount of credit outstanding (in bolivianos) in year t. $Income_{it}$ is equal to earnings from sales of goods, wage labor, and barter over the last two weeks in year t, the respective percentiles of which are conditional on $Income_{it}$ being non-zero. Standard deviations are in parentheses.

Table 4: Determinants of Financing Portfolio

	Dependent variable: *Proportion Funds Borrowed from Villager*$_{it}$			
Member of large group$_i$	0.148**	0.159***	0.200***	0.220***
$\times$ *Ability*$_{i,t-1}$	[0.06]	[0.06]	[0.07]	[0.07]
Member of large group$_i$	0.001	-0.002		
	[0.06]	[0.06]		
Ability$_{i,t-1}$	-0.095**	-0.081**	-0.045	-0.055
	[0.04]	[0.04]	[0.05]	[0.05]
Other controls	No	Yes	No	Yes
Fixed effects	Village	Village	Individual, village-year	Individual, village-year
# of observations	808	795	808	795
# of individuals	419	415	419	415

Notes: */**/*** denote significance at the 10%/5%/1% level, respectively. *Proportion Funds Borrowed from Villager*$_{it}$ $\in [0,1]$ denotes, conditional on receiving any non-zero amount of credit, the proportion of funds held in intra-village equity by i during the 54 weeks before year t. Standard errors are clustered at the household level, and, whenever applicable, other controls include an indicator for being household head, gender, household size, wealth in traditional assets, and total borrowings in year t.

Table 5a: Perfect Risk Sharing in the Large Group

	Dependent variable: c_{it}		Dependent variable: $c_{it} - c_{vt}$	
c_{vt}	0.826***	0.927***		
	[0.17]	[0.12]		
$Income_{it}$	0.204*	-0.000	0.214*	-0.002
	[0.10]	[0.11]	[0.09]	[0.11]
# of negative idiosyncratic shocks	1	0	2	0
Sample	Small group	Large group	Small group	Large group
Fixed effects	Household	Household	Household	Household
# of observations	343	933	343	933
# of individuals	127	361	127	361

	Dependent variable: $\Delta \ln c_{it}$		Dependent variable: $\Delta \ln c_{it} - \Delta \ln c_{vt}$	
$\Delta \ln c_{vt}$	0.757***	1.003***		
	[0.17]	[0.14]		
$\Delta \ln Income_{it}$	0.118	-0.000	0.128	-0.000
	[0.09]	[0.05]	[0.09]	[0.05]
# of negative idiosyncratic shocks	3	0	3	0
Sample	Small group	Large group	Small group	Large group
Fixed effects	Household	Household	Household	Household
# of observations	217	559	217	559
# of individuals	105	278	105	278

Notes (Tables 5a and 5b): */**/*** denote significance at the 10%/5%/1% level, respectively. In the (household) fixed effects regressions, standard errors are clustered at the village level. Controls for the following idiosyncratic shocks are included: animal loss, crop loss, family death, fire, flood, health, theft, divorce, and "other." An idiosyncratic shock is indicated as negative if it is at least significant at the 10% level. c_{it} and c_{vt} denote the weekly consumption of game, fish, eggs, maize, manioc, rice, oil, and bread (in bolivianos) on the household and average village (excluding i) level, respectively. $Income_{it}$ is equal to earnings from sales of goods, wage labor, and barter for one week.

Table 5b: Perfect Risk Sharing in the Large Group

	Dependent variable: c_{it}		Dependent variable: $c_{it} - c_{gt}$	
c_{gt}	1.107***	0.932***		
	[0.36]	[0.10]		
$c_{vt} - c_{gt}$	0.656***	0.924***	0.656**	0.924***
	[0.21]	[0.18]	[0.21]	[0.18]
$Income_{it}$	0.195*	-0.000	0.195*	0.001
	[0.10]	[0.11]	[0.10]	[0.11]
# of negative idiosyncratic shocks	1	0	2	0
Sample	Small group	Large group	Small group	Large group
Fixed effects	Household	Household	Household	Household
# of observations	343	933	343	933
# of individuals	127	361	127	361
	Dependent variable: $\Delta \ln c_{it}$		Dependent variable: $\Delta \ln c_{it} - \Delta \ln c_{gt}$	
$\Delta \ln c_{gt}$	1.238***	1.166***		
	[0.30]	[0.23]		
$\Delta \ln c_{vt} - \Delta \ln c_{gt}$	0.442***	0.807***	0.438***	0.827***
	[0.10]	[0.24]	[0.12]	[0.21]
$\Delta \ln Income_{it}$	0.124	0.003	0.118	0.003
	[0.08]	[0.05]	[0.08]	[0.05]
# of negative idiosyncratic shocks	3	0	3	0
Sample	Small group	Large group	Small group	Large group
Fixed effects	Household	Household	Household	Household
# of observations	217	559	217	559
# of individuals	105	278	105	278

Notes: c_{it}, c_{vt}, and c_{gt} denote the weekly consumption of game, fish, eggs, maize, manioc, rice, oil, and bread (in bolivianos) on the household level, average village level (excluding i), and on average across all villages (excluding i), respectively.

Table 6a: Human Capital Outcomes and Changes in Leverage (LPM)

	Dependent variable: *Marginal human capital investment*$_{it}$			
Δ*Leverage ratio*$_{it}$			0.050**	0.060**
			[0.02]	[0.03]
Ability$_{i,t-1}$	0.035**	0.039*	0.019	0.006
	[0.01]	[0.02]	[0.02]	[0.04]
Proxy for p_{it}	0.167***	0.167***	0.241***	0.249***
	[0.02]	[0.02]	[0.03]	[0.04]
1/*Pig selling price*$_{it}$	3.607*	2.483	11.332***	11.776***
	[1.98]	[2.10]	[2.27]	[2.65]
Ability$_{i,t-1}$			-0.038**	-0.056**
$\times$ Δ*Leverage ratio*$_{it}$			[0.02]	[0.02]
Proxy for p_{it}			-0.047**	-0.060**
$\times\Delta$*Leverage ratio*$_{it}$			[0.02]	[0.03]
1/*Pig selling price*$_{it}$			-4.079*	-1.765
$\times$ Δ*Leverage ratio*$_{it}$			[2.31]	[2.72]
Δ*Traditional assets*$_{it}$	0.020*	0.018	0.026*	0.034*
	[0.01]	[0.01]	[0.01]	[0.02]
Currently in school$_{it}$	0.083***	0.036*	-0.008	-0.017
	[0.02]	[0.02]	[0.02]	[0.03]
Fixed effects	Village	Individual, village	Village	Individual, village
# of observations	3,417	3,417	1,159	1,159
# of individuals	1,153	1,153	556	556

Notes: */**/*** denote significance at the 10%/5%/1% level, respectively. *Marginal human capital investment*$_{it}$ $\in \{0, 1\}$ indicates whether i's Spanish speaking and/or reading skills improved since $t-1$. In the linear probability model regressions, standard errors are clustered at the household level. Whenever applicable, regressions include controls for being household head, gender, household size, the number of teachers in i's village, alternative human capital measures, and both parents' Spanish speaking and reading skills. Δ*Leverage ratio*$_{it}$ denotes the log change of i's net total borrowings over bi-weekly earnings from sales of goods, wage labor, and barter. *Ability*$_{i,t-1}$ denotes the ratio of i's score (between 0 and 4) on last period's math test to years of education. The proxy for p is a dummy for whether any people left i's village to move to the next biggest town – a sufficient indicator for their having found a job – and *Pig selling price*$_{it}$ equals the village selling price of a one-year old pig (in bolivianos) in the last three months of year t. Δ*Traditional assets*$_{it}$ denotes the log change of i's traditional assets, and *Currently in school*$_{it}$ is an indicator variable.

Table 6b: Human Capital Outcomes and Changes in Leverage (Probit)

	Dependent variable: *Marginal human capital investment*$_{it}$			
Δ*Leverage ratio*$_{it}$			0.480***	0.480***
			[0.18]	[0.13]
Ability$_{i,t-1}$	0.125**	0.125*	0.143	0.143
	[0.06]	[0.07]	[0.15]	[0.11]
Proxy for p_{it}	0.824***	0.824***	1.747***	1.747***
	[0.09]	[0.22]	[0.27]	[0.68]
1/*Pig selling price*$_{it}$	17.929*	17.929	116.407***	116.407**
	[9.98]	[22.90]	[22.91]	[51.43]
Ability$_{i,t-1}$			-0.358**	-0.358**
$\times$ Δ*Leverage ratio*$_{it}$			[0.14]	[0.11]
Proxy for p_{it}			-0.313***	-0.313***
$\times\Delta$*Leverage ratio*$_{it}$			[0.12]	[0.14]
1/*Pig selling price*$_{it}$			-25.134*	-25.134**
$\times$ Δ*Leverage ratio*$_{it}$			[13.44]	[10.62]
Δ*Traditional assets*$_{it}$	0.070	0.070	0.264*	0.264
	[0.06]	[0.10]	[0.15]	[0.18]
Currently in school$_{it}$	0.392***	0.392***	0.061	0.061
	[0.07]	[0.07]	[0.25]	[0.20]
Standard error clustering	Household level	Village level	Household level	Village level
Fixed effects	Village	Village	Village	Village
# of observations	3,416	3,416	1,159	1,159
# of individuals	1,153	1,153	556	556

Notes: */**/*** denote significance at the 10%/5%/1% level, respectively. The pooled probit regressions use the same variables as in Table 6a.

Table 7a: Who Gets Which Contract? (First Stage)

	Dependent variable: *Majority funds from villager*$_{it}$		Dependent variable: *Majority funds from outside*$_{it}$	
Cost of divorce shocks$_{vt}$		-0.019**		0.041***
		[0.01]		[0.01]
Member of large group$_i$	0.094***		-0.077	
$\times$ *Ability*$_{i,t-1}$	[0.03]		[0.07]	
Member of large group$_i$	-0.007	0.029	0.059*	0.014
	[0.02]	[0.02]	[0.03]	[0.03]
Ability$_{i,t-1}$	-0.072***	-0.004	0.092	0.048
	[0.03]	[0.03]	[0.07]	[0.03]
Adjusted R^2	0.067	0.081	0.231	0.243
Fixed effects	Village	Village	Village	Village
# of observations	1,114	807	1,114	807
# of individuals	527	453	527	453

Notes: */**/*** denote significance at the 10%/5%/1% level, respectively. *Majority funds from villager*$_{it}$ and *Majority funds from outside*$_{it}$ are indicator variables for whether i borrowed the majority of his funds in intra-village equity or extra-village debt during the 54 weeks before year t. In the linear probability model regressions, standard errors are clustered at the household level, and regressions include all of the regressors from Tables 6a and 6b besides the following instruments: *Cost of divorce shocks*$_{vt}$ is the average cost due to divorce incurred by villagers in v (except i) at time t, and *Member of large group*$_i \times$ *Ability*$_{i,t-1}$ is an interaction effect where *Member of large group*$_i$ is a dummy for whether i belongs to a household that practices cross-cousin marriage and *Ability*$_{i,t-1}$ denotes the ratio of i's score (between 0 and 4) on last period's math test to years of education.

Table 7b: Human Capital Outcomes and Contract Choice (Second Stage)

	Dependent variable: *Marginal human capital investment*$_{it}$			
Majority funds from villager$_{it}$	-0.054**	-0.126**	0.585*	3.418*
(endogenous)	[0.02]	[0.05]	[0.34]	[1.78]
Member of large group$_i$	0.003		-0.008	-0.092
	[0.02]		[0.02]	[0.08]
Instrument	None	None	(I)	(II)
AR test (p-value)			0.03	0.00
Fixed effects	Village	Individual, village-year	Village	Village
# of observations	1,114	1,114	1,114	807
# of individuals	527	527	527	453

	Dependent variable: *Marginal human capital investment*$_{it}$			
Majority funds from outside$_{it}$	-0.031	0.012	-0.716	-1.614**
(endogenous)	[0.02]	[0.04]	[0.75]	[0.67]
Member of large group$_i$	0.003		0.030	0.028
	[0.02]		[0.04]	[0.06]
Instrument	None	None	(I)	(II)
AR test (p-value)			0.03	0.00
Fixed effects	Village	Individual, village-year	Village	Village
# of observations	1,114	1,114	1,114	807
# of individuals	527	527	527	453

Notes: */**/*** denote significance at the 10%/5%/1% level, respectively. *Marginal human capital investment*$_{it}$ $\in \{0, 1\}$ indicates whether i's Spanish speaking and/or reading skills improved since $t-1$. In the linear probability model regressions, standard errors are clustered at the household level, and regressions include all of the regressors from Tables 6a and 6b besides *Member of large group*$_i$, and – in the third and fourth columns – account for potential endogeneity by the following instruments: (I) = *Member of large group*$_i$ $\times$ *Ability*$_{i,t-1}$ and (II) = *Cost of divorce shocks*$_{vt}$. First-stage results of the instruments are given in the first two rows of Table 7a.

Table 7c: Human Capital Outcomes and Contract Choice (Reduced Form)

	Dependent variable: *Marginal human capital investment$_{it}$*		
Cost of divorce shocks$_{vt}$		-0.066***	-0.066***
		[0.02]	[0.02]
Member of large group$_i$	0.055**		0.082**
$\times$ *Ability$_{i,t-1}$*	[0.03]		[0.04]
Member of large group$_i$	-0.012	0.006	-0.016
	[0.02]	[0.02]	[0.02]
Fixed effects	Village	Village	Village
# of observations	1,114	807	807
# of individuals	527	453	453

Notes: */**/*** denote significance at the 10%/5%/1% level, respectively. *Marginal human capital investment$_{it}$* $\in \{0, 1\}$ indicates whether i's Spanish speaking and/or reading skills improved since $t-1$. In the linear probability model regressions, standard errors are clustered at the household level, and regressions include all of the regressors from Tables 6a and 6b besides the following instruments: *Cost of divorce shocks$_{vt}$* is the average cost due to divorce incurred by villagers in v (except i) at time t, and *Member of large group$_i$* $\times$ *Ability$_{i,t-1}$* is an interaction effect where *Member of large group$_i$* is a dummy for whether i belongs to a household that practices cross-cousin marriage and *Ability$_{i,t-1}$* denotes the ratio of i's score (between 0 and 4) on last period's math test to years of education.

Table 8: Baseline Parameter Values

	CARA	CRRA
X^H	600	900
X^L	300	450
p	0.8	0.8
c_i	$\alpha - \beta Ability_i$	$\alpha - \beta Ability_i$
α	200	298
β	4.7 to 7.2 in steps of 0.5	6.2 to 7.2 in steps of 0.5
$I - W$	318	477
Coefficient of ARA/RRA	0.007	2
θ_{aa}	$\frac{0.1858}{0.7432}$	$\frac{0.1858}{0.7432}$
θ_{an}	$\frac{0.5574}{0.7432}$	$\frac{0.5574}{0.7432}$

Notes: The first column presents the baseline parameters for a borrower with constant absolute risk aversion. The second column presents the baseline parameters for a borrower with constant relative risk aversion. $Ability_i$ is equal to the first observation of $Ability_{it}$ for i. θ_{aa} and θ_{an} denote the empirical population densities for risk averse villagers borrowing in- and outside their village, respectively.

Table 9: Counterfactual Increase in Human Capital Investment for Risk Averse Borrowers (CARA) in a Perfect Capital Market

$\widetilde{e} - e$ (given population)	$\widetilde{e} - e$ (assuming $\theta_{an} = 1$)	β	Average Cost Adjustment
0.3251	0.4335	4.7	No
[0.0134]			
0.3255	0.4340	5.2	No
[0.0135]			
0.3260	0.4347	5.7	No
[0.0137]			
0.3265	0.4353	6.2	No
[0.0143]			
0.3269	0.4359	6.7	No
[0.0145]			
0.3278	0.4371	7.2	No
[0.0153]			
0.3309	0.4412	4.7	Yes
[0.0087]			
0.3314	0.4419	5.2	Yes
[0.0086]			
0.3320	0.4427	5.7	Yes
[0.0086]			
0.3331	0.4441	6.2	Yes
[0.0089]			
0.3336	0.4448	6.7	Yes
[0.0088]			
0.3355	0.4473	7.2	Yes
[0.0091]			

Notes (Tables 9 and 10): $\widetilde{e} - e$ (as defined in (15) and (16)) is the calibrated mean difference in portfolio weights on human capital investment for risk averse borrowers of equity and debt provided by risk neutral lenders. Standard deviations are given in parentheses. β is the sensitivity of the marginal cost of human capital investment to learning productivity: $\alpha - \beta Ability_i$ where $Ability_i$ is equal to the first observation of $Ability_{it}$ for i. When using average cost adjustment, the marginal cost of human capital investment c is homogeneous, i.e., $c = \frac{1}{n}\sum_{i=1}^{n} c_i = \alpha - \frac{\beta}{n}\sum_{i=1}^{n} Ability_i$.

Table 10: Counterfactual Increase in Human Capital Investment for Risk Averse Borrowers (CRRA) in a Perfect Capital Market

$\widetilde{e}-e$ (given population)	$\widetilde{e}-e$ (assuming $\theta_{an}=1$)	β	Average Cost Adjustment
0.1520	0.2027	6.2	No
[0.0829]			
0.1516	0.2021	6.7	No
[0.0829]			
0.1509	0.2012	7.2	No
[0.0830]			
0.1665	0.2220	6.2	Yes
[0.0587]			
0.1662	0.2216	6.7	Yes
[0.0588]			
0.1655	0.2207	7.2	Yes
[0.0588]			

Proofs

Proof of Proposition 1 Given the borrower's risk neutrality and the assumption that human capital has a higher expected return than foraging-farming, the borrower's utility is increasing in e^* (cf. (8) and (10)). Hence, one can show Proposition 1 by comparing equilibrium levels of $1-\delta^*$ and $\frac{\Delta R^*}{\Delta X}$, i.e., the shares of ΔX retained by the lender. The borrower will prefer debt to equity if $1-\delta^* > \frac{\Delta R^*}{\Delta X}$. To show this, I first determine δ^* and ΔR^* from the lender's participation constraint. For the latter, one has from (9):

$$R^L + \Delta R \frac{\Delta X - \Delta R}{c} = I - W \Leftrightarrow X^L + \Delta R \frac{\Delta X - \Delta R}{c} = I - W$$

$$\Leftrightarrow \Delta R \left(\Delta X - \Delta R\right) = c\left(I - W - X^L\right)$$

$$\Leftrightarrow \left(\Delta R\right)^2 - \Delta R \Delta X + c\left(I - W - X^L\right) = 0$$

The lender will then set ΔR according to:

$$\Delta R^* = \frac{\Delta X}{2} \pm \frac{1}{2}\sqrt{\left(\Delta X\right)^2 - 4c\left(I - W - X^L\right)}$$

Now, for the optimal equity contract, one has from (11):

$$I - W = \delta(1-\delta)\frac{(\Delta X)^2}{c} + (1-\delta)X^L \Leftrightarrow I - W = \delta\frac{(\Delta X)^2}{c} - \delta^2\frac{(\Delta X)^2}{c} - \delta X^L + X^L$$

$$\Leftrightarrow \delta^2\frac{(\Delta X)^2}{c} + \delta\left(X^L - \frac{(\Delta X)^2}{c}\right) - X_L + I - W = 0$$

$$\Leftrightarrow \delta^2 + \delta\left(\frac{X^L c}{(\Delta X)^2} - 1\right) - c\frac{X^L - I + W}{(\Delta X)^2} = 0$$

The lender will choose δ s.t.:

$$\delta^* = \frac{1}{2}\left(1 - \frac{X^L c}{(\Delta X)^2}\right) \pm \frac{1}{2}\sqrt{\left(1 - \frac{X^L c}{(\Delta X)^2}\right)^2 - 4c\frac{I - W - X^L}{(\Delta X)^2}}$$

By assumption (perfect competition among lenders), intra- and extra-village lenders offer contracts s.t. $1-\delta^*$ and ΔR^* are the smallest possible values that fulfill the lender's participation constraint. Then, it is sufficient to show that:

$$1 - \delta^* > \frac{\Delta R^*}{\Delta X} \Leftrightarrow \frac{1}{2} + \frac{1}{2}\frac{X^L c}{(\Delta X)^2} - \frac{1}{2}\sqrt{\left(1 - \frac{X^L c}{(\Delta X)^2}\right)^2 - 4c\frac{I - W - X^L}{(\Delta X)^2}} > \frac{1}{2} - \frac{1}{2}\sqrt{1 - \frac{4c(I - W - X^L)}{(\Delta X)^2}}$$

which is true because $\sqrt{\left(1 - \frac{X^L c}{(\Delta X)^2}\right)^2 - 4c\frac{I - W - X^L}{(\Delta X)^2}} < \sqrt{1 - \frac{4c(I - W - X^L)}{(\Delta X)^2}}$, so the borrower prefers debt to equity. ■

Proof of Proposition 2 Compared to the case of risk neutrality, the relationship between required funding and the utility from granting debt or equity is determined by the variability of the claims, that is:

$$U(I-W) \geq pU\left(e_d^* \frac{\Delta R^* + X^L}{p} + (1-e_d^*) X^L\right) + (1-p)U\left((1-e_d^*) X^L\right)$$

and

$$U(I-W) \geq pU\left((1-\delta^*)\left(e_e^* X^H + (1-e_e^*) X^L\right)\right) + (1-p)U\left((1-\delta^*)(1-e_e^*) X^L\right)$$

where $e_d^* > e_e^*$ denote the borrower's optimal portfolio weights with debt and equity, respectively, granted by the risk neutral lender.

Denote $G\left(\frac{\Delta R}{\Delta X}\right) \equiv pU\left(e\frac{\Delta R + X^L}{p} + (1-e) X^L\right) + (1-p)U\left((1-e) X^L\right)$ and $H(1-\delta) \equiv pU\left((1-\delta)\left(eX^H + (1-e) X^L\right)\right) + (1-p)U\left((1-\delta)(1-e) X^L\right)$. As $U'(\cdot) > 0$ and $G\left(\frac{\Delta R}{\Delta X}\right)\Big|_{e=e_d^*} \leq U(I-W) \leq U(F^{max})$ where marginal utility (wrt $\frac{\Delta R}{\Delta X}$ and $(1-\delta)$) is zero, and by A2, one has that:

$$\left.\frac{\partial G}{\partial \frac{\Delta R}{\Delta X}}\right|_{e=e_d^*} > 2\min\left\{\begin{array}{c} pU'\left(e\frac{\Delta R + X^L}{p} + (1-e) X^L\right), \\ (1-p)U'\left((1-e) X^L\right)\end{array}\right\} \left.\frac{\partial\left[e\frac{\Delta R + X^L}{p} + 2(1-e) X^L\right]}{\partial \frac{\Delta R}{\Delta X}}\right|_{e=e_d^*} > 0$$

That is, given the lender's risk aversion, he will not decrease $\frac{\Delta R}{\Delta X}$, so $\frac{\Delta R^*}{\Delta X} \leq \frac{\Delta R^{**}}{\Delta X}$. However, whenever the risk neutral borrower is indifferent between debt and equity, i.e., $\frac{\Delta R}{\Delta X} = 1-\delta$ (and thus e does not vary with the form of financing), the lender prefers debt to equity:

$$\frac{\Delta R}{\Delta X} = 1-\delta \Leftrightarrow \Delta R = (1-\delta)\Delta X \Leftrightarrow pR^H = pX^H - \delta\Delta X = R^H = (1-\delta) X^H + \frac{\delta X^L}{p} > (1-\delta)X^H \Rightarrow G\left(\frac{\Delta R}{\Delta X}\right) > H\left(\frac{\Delta R}{\Delta X}\right)$$

In combination with $\left.\frac{\partial G}{\partial \frac{\Delta R}{\Delta X}}\right|_{e=e_d^*} > 0$, one can conclude that $\frac{\Delta R^{**}}{\Delta X}$ is the smallest possible solution to the lender's participation constraint. In order to attain $U(I-W)$, the risk averse lender will offer debt and equity contracts s.t. $\frac{\Delta R^{**}}{\Delta X} < 1-\delta^{**} \Rightarrow e_d^{**} > e_e^{**}$, and the borrower prefers debt to equity. ■

Proof of Proposition 3 The equilibrium contract determinants $\frac{\Delta\widetilde{R}^*}{\Delta\widetilde{X}}$ and $1-\delta^*$ are derived from the lender's participation constraint. In equilibrium, the lender is indifferent between providing debt and equity, i.e., $\frac{\ln\left(\frac{p}{1-p}\frac{\Delta\widetilde{X}-\Delta\widetilde{R}-c}{c}\right)}{\Delta\widetilde{X}-\Delta\widetilde{R}}\left(pR^H-X^L\right)+X^L=(1-\delta)\frac{\ln\left(\frac{p}{1-p}\frac{\delta\Delta\widetilde{X}-c}{\delta X^L+c}\right)}{\delta X^H}\left(pX^H-X^L\right)+(1-\delta)X^L=I-W$. Assume that $\frac{\Delta\widetilde{R}}{\Delta\widetilde{X}}=1-\delta$. But then:

$$\frac{\ln\left(\frac{p}{1-p}\frac{\Delta\widetilde{X}-\Delta\widetilde{R}-c}{c}\right)}{\Delta\widetilde{X}-\Delta\widetilde{R}}\left(pR^H-X^L\right)+\delta X^L>(1-\delta)\frac{\ln\left(\frac{p}{1-p}\frac{\delta\Delta\widetilde{X}-c}{\delta X^L+c}\right)}{\delta X^H}\left(pX^H-X^L\right)$$

To see this, insert $\frac{\Delta\widetilde{R}}{\Delta\widetilde{X}}=1-\delta$ in the participation constraint for debt, and use $e_d^*\leq 1$:

$$\frac{\ln\left(\frac{p}{1-p}\frac{\Delta\widetilde{X}-\Delta\widetilde{R}-c}{c}\right)}{\Delta\widetilde{X}-\Delta\widetilde{R}}\left(pR^H-X^L\right)+\delta X^L=\ln\left(\frac{p}{1-p}\frac{\delta\Delta\widetilde{X}-c}{c}\right)\frac{(1-\delta)\left(pX^H-X^L\right)-(1-p)\delta X^L}{\delta\Delta\widetilde{X}}+\delta X^L$$

$$>(1-\delta)\ln\left(\frac{p}{1-p}\frac{\delta\Delta\widetilde{X}-c}{c}\right)\frac{pX^H-X^L}{\delta\Delta\widetilde{X}}>(1-\delta)\frac{\ln\left(\frac{p}{1-p}\frac{\delta\Delta\widetilde{X}-c}{\delta X^L+c}\right)}{\delta\Delta\widetilde{X}}\left(pX^H-X^L\right)$$

$$>(1-\delta)\frac{\ln\left(\frac{p}{1-p}\frac{\delta\Delta\widetilde{X}-c}{\delta X^L+c}\right)}{\delta X^H}\left(pX^H-X^L\right).$$

From this, one can conclude that $\frac{\Delta\widetilde{R}}{\Delta\widetilde{X}}=1-\delta$ is not an equilibrium solution. In equilibrium, it holds that $\frac{\Delta\widetilde{R}^*}{\Delta\widetilde{X}}>1-\delta^*$ if the term $J\left(\frac{\Delta\widetilde{R}}{\Delta\widetilde{X}}\right)\equiv\frac{\ln\left(\frac{p}{1-p}\frac{\Delta\widetilde{X}-\Delta\widetilde{R}-c}{c}\right)}{\Delta\widetilde{X}-\Delta\widetilde{R}}\left(pR^H-X^L\right)+X^L$ is decreasing in $\frac{\Delta\widetilde{R}}{\Delta\widetilde{X}}$. To see that the latter condition is true, note that, by using the implicit function theorem on the lender's participation constraint, one yields:

$$\frac{\partial e_d^*}{\partial\frac{\Delta\widetilde{R}}{\Delta\widetilde{X}}}\leq\frac{\frac{pX^H-X^L}{\Delta\widetilde{X}-\Delta\widetilde{R}}\frac{\Delta\widetilde{X}}{\Delta\widetilde{X}-\Delta\widetilde{R}-c}-e_d^*\frac{\Delta\widetilde{X}\left(p(\Delta\widetilde{X}-\Delta\widetilde{R})+pR^H-X^L\right)}{\Delta\widetilde{X}-\Delta\widetilde{R}}}{pR^H-X^L}=\frac{\Delta\widetilde{X}\frac{pX^H-X^L}{\Delta\widetilde{X}-\Delta\widetilde{R}}\left(\frac{1}{\Delta\widetilde{X}-\Delta\widetilde{R}-c}-\frac{\ln\left(\frac{p}{1-p}\frac{\Delta\widetilde{X}-\Delta\widetilde{R}-c}{c}\right)}{\Delta\widetilde{X}-\Delta\widetilde{R}}\right)}{pR^H-X^L}$$

because $R^H\leq X^H$.

The denominator must be positive because the lender of debt cannot break even otherwise. Given A3, $\frac{\partial e_d^*}{\partial\frac{\Delta\widetilde{R}}{\Delta\widetilde{X}}}<0$ follows if $\frac{\ln\left(\frac{p}{1-p}\frac{\Delta\widetilde{X}-\Delta\widetilde{R}-c}{c}\right)}{\Delta\widetilde{X}-\Delta\widetilde{R}}>\frac{1}{(1-p)X^H+X^L-R^H}$. Suppose this were not true, i.e., $\frac{\ln\left(\frac{p}{1-p}\frac{\Delta\widetilde{X}-\Delta\widetilde{R}-c}{c}\right)}{\Delta\widetilde{X}-\Delta\widetilde{R}}\leq\frac{1}{(1-p)X^H+X^L-R^H}$. Also, note that, for e_d^* to be positive, one requires $X^H-R^H>\frac{c}{p}$. Then, the lender's participation constraint would not be fulfilled as:

$$e_d^*\left(pR^H-X^L\right)+X^L\leq\frac{pR^H-X^L}{(1-p)X^H+X^L-R^H}+X^L<p\frac{pX^H-X^L}{c+pX^L-p^2X^H}+X^L<X^L<I-W$$

because $c<p^2X^H-pX^L$ (by A3). Hence it follows that $\frac{\partial e_d^*}{\partial\frac{\Delta\widetilde{R}}{\Delta\widetilde{X}}}<0$, which one can use to derive:

$$\frac{\partial J}{\partial \frac{\Delta \widetilde{R}}{\Delta \widetilde{X}}} = \frac{\Delta \widetilde{X}}{\Delta \widetilde{X}-\Delta \widetilde{R}} \left(\frac{pR^H - X^L}{\Delta \widetilde{X}-\Delta \widetilde{R}-c} - \left(pX^H - X^L\right) \frac{\ln\left(\frac{p}{1-p}\frac{\Delta \widetilde{X}-\Delta \widetilde{R}-c}{c}\right)}{\Delta \widetilde{X}-\Delta \widetilde{R}} \right) + \frac{\ln\left(\frac{p}{1-p}\frac{\Delta \widetilde{X}-\Delta \widetilde{R}-c}{c}\right)}{\Delta \widetilde{X}-\Delta \widetilde{R}} p\Delta \widetilde{X} < 0$$

$$\Leftrightarrow \frac{pR^H - X^L}{\Delta \widetilde{X}-\Delta \widetilde{R}-c} - \left(pX^H - X^L\right) \frac{\ln\left(\frac{p}{1-p}\frac{\Delta \widetilde{X}-\Delta \widetilde{R}-c}{c}\right)}{\Delta \widetilde{X}-\Delta \widetilde{R}} < \frac{\ln\left(\frac{p}{1-p}\frac{\Delta \widetilde{X}-\Delta \widetilde{R}-c}{c}\right)}{\Delta \widetilde{X}-\Delta \widetilde{R}} p\left(\Delta \widetilde{R} - \Delta \widetilde{X}\right)$$

$$\Leftrightarrow \frac{pR^H - X^L}{\Delta \widetilde{X}-\Delta \widetilde{R}-c} < \left(pR^H - X^L\right) \frac{\ln\left(\frac{p}{1-p}\frac{\Delta \widetilde{X}-\Delta \widetilde{R}-c}{c}\right)}{\Delta \widetilde{X}-\Delta \widetilde{R}}$$

which holds as shown above. Hence, $\frac{\Delta \widetilde{R}^*}{\Delta \widetilde{X}} > 1 - \delta^*$ in equilibrium.

As seen and used above, $e_d > e_e$ if $\frac{\Delta \widetilde{R}}{\Delta \widetilde{X}} = 1 - \delta$. As $\frac{\partial e_d^*}{\partial \frac{\Delta \widetilde{R}}{\Delta \widetilde{X}}} < 0$, one can conclude that $e_d^* < e_e^*$ if even increasing $\frac{\Delta \widetilde{R}}{\Delta \widetilde{X}}$ to the point that $e_d = e_e$ does not lead to the lender's indifference between debt and equity. That is, assume that $e_d = e_e$, and one already knows that $\frac{\Delta \widetilde{R}^*}{\Delta \widetilde{X}} > 1 - \delta^* \Rightarrow R^{H*} = (1-\delta^*)\, X^H + \delta^* X^L > (1-\delta^*)\, X^H$, then one obtains:

$$e_d\left(pR^{H*} - X^L\right) = e_e\left(pR^{H*} - X^L\right) > e_e\left((1-\delta^*)pX^H - X^L\right) \geq$$
$$(1-\delta^*)e_e\left(pX^H - X^L\right) - \delta^* X^L$$

because $e_e \leq 1$. Hence, it must hold that $e_d^* < e_e^*$ in equilibrium.

Finally, for the borrower's utility to *increase* in e^*, it must hold that e_d^* and e_e^* are *lower* than in the first-best case. For this, it is sufficient to show that $\frac{\ln\left(\frac{p}{1-p}\frac{\delta \Delta \widetilde{X}-c}{\delta X^L + c}\right)}{\delta X^H} = e_e^* < e_{fb}^* = \frac{\ln\left(\frac{p}{1-p}\frac{\Delta \widetilde{X}-c}{X^L + c}\right)}{X^H}$, which is true by A4 and the fact that, for e_e^* to be positive, one requires $pX^H - X^L > \frac{c}{\delta}$. To demonstrate this: $\frac{p\left(\Delta \widetilde{X}-c\right)}{X^L+c} \leq \frac{(1-p)c}{pX^H - X^L} \Rightarrow \frac{(1-\delta)p}{(1-p)(X^L+c)} < \frac{\delta}{\delta \Delta \widetilde{X}-c} \Rightarrow (1-\delta)\ln\left(\frac{p}{1-p}\frac{\Delta \widetilde{X}-c}{X^L+c}\right) < \ln\left(\frac{p}{1-p}\frac{(1-\delta)\left(\Delta \widetilde{X}-c\right)}{X^L+c}\right) < \ln\left(\frac{\delta\left(\Delta \widetilde{X}-c\right)}{\delta \Delta \widetilde{X}-c}\right) \Rightarrow e_e^* < e_{fb}^*$. ■

Proof of Proposition 4 Given the lender's risk aversion, one has:

$$U(I-W) \geq pU\left(e_d^*\left(\Delta\widetilde{R}^* + X^L\right) + \left(1-e_d^*\right)X^L\right) + (1-p)U\left(\left(1-e_d^*\right)X^L\right)$$

and

$$U(I-W) \geq pU\left((1-\delta^*)\left(e_e^* X^H + \left(1-e_e^*\right)X^L\right)\right) + (1-p)U\left((1-\delta^*)\left(1-e_e^*\right)X^L\right)$$

where $e_d^* > e_e^*$ denote the borrower's optimal portfolio weights with debt and equity, respectively, granted by the risk neutral lender.

Denote $G\left(\frac{\Delta\widetilde{R}}{\Delta\widetilde{X}}\right) \equiv pU\left(e\left(\Delta\widetilde{R} + X^L\right) + (1-e)X^L\right) + (1-p)U\left((1-e)X^L\right)$ as well as $H(1-\delta) \equiv pU\left((1-\delta)\left(eX^H + (1-e)X^L\right)\right) + (1-p)U\left((1-\delta)(1-e)X^L\right)$.

Now, for $\frac{\partial G\left(\frac{\Delta\widetilde{R}}{\Delta\widetilde{X}}\right)}{\partial\frac{\Delta\widetilde{R}}{\Delta\widetilde{X}}}$ to be negative, it is sufficient to show that $K\left(\frac{\Delta\widetilde{R}}{\Delta\widetilde{X}}\right) \equiv \frac{\ln\left(\frac{p}{1-p}\frac{\Delta\widetilde{X}-\Delta\widetilde{R}-c}{c}\right)}{\Delta\widetilde{X}-\Delta\widetilde{R}}\left(R^H - 2X^L\right) + 2X^L$ is decreasing in $\frac{\Delta\widetilde{R}}{\Delta\widetilde{X}}$, the proof of which is similar to that of Proposition 3, and is conducted in two steps. First, $\operatorname{sign}\left(\frac{\partial e_d^*}{\partial\frac{\Delta\widetilde{R}}{\Delta\widetilde{X}}}\right) = \operatorname{sign}\left(\frac{\Delta\widetilde{X}}{\Delta\widetilde{X}-\Delta\widetilde{R}}\left(\frac{R^H-2X^L}{\Delta\widetilde{X}-\Delta\widetilde{R}-c} - \left(X^H - 2X^L\right)\frac{\ln\left(\frac{p}{1-p}\frac{\Delta\widetilde{X}-\Delta\widetilde{R}-c}{c}\right)}{\Delta\widetilde{X}-\Delta\widetilde{R}}\right)\right) < 0$ due to A3. Then:

$$\operatorname{sign}\left(\frac{\partial K}{\partial\frac{\Delta\widetilde{R}}{\Delta\widetilde{X}}}\right) =$$

$$\operatorname{sign}\left(\frac{\Delta\widetilde{X}}{\Delta\widetilde{X}-\Delta\widetilde{R}}\left(\frac{R^H-2X^L}{\Delta\widetilde{X}-\Delta\widetilde{R}-c} - \left(X^H - 2X^L\right)\frac{\ln\left(\frac{p}{1-p}\frac{\Delta\widetilde{X}-\Delta\widetilde{R}-c}{c}\right)}{\Delta\widetilde{X}-\Delta\widetilde{R}}\right) + \frac{\ln\left(\frac{p}{1-p}\frac{\Delta\widetilde{X}-\Delta\widetilde{R}-c}{c}\right)}{\Delta\widetilde{X}-\Delta\widetilde{R}}\Delta\widetilde{X}\right) < 0$$

because

$$\frac{\Delta\widetilde{X}}{\Delta\widetilde{X}-\Delta\widetilde{R}}\left(\frac{R^H-2X^L}{\Delta\widetilde{X}-\Delta\widetilde{R}-c} - \left(X^H - 2X^L\right)\frac{\ln\left(\frac{p}{1-p}\frac{\Delta\widetilde{X}-\Delta\widetilde{R}-c}{c}\right)}{\Delta\widetilde{X}-\Delta\widetilde{R}}\right) + \frac{\ln\left(\frac{p}{1-p}\frac{\Delta\widetilde{X}-\Delta\widetilde{R}-c}{c}\right)}{\Delta\widetilde{X}-\Delta\widetilde{R}}\Delta\widetilde{X} < 0$$

$$\Leftrightarrow \frac{R^H-2X^L}{\Delta\widetilde{X}-\Delta\widetilde{R}-c} - \left(X^H - 2X^L\right)\frac{\ln\left(\frac{p}{1-p}\frac{\Delta\widetilde{X}-\Delta\widetilde{R}-c}{c}\right)}{\Delta\widetilde{X}-\Delta\widetilde{R}} < \frac{\ln\left(\frac{p}{1-p}\frac{\Delta\widetilde{X}-\Delta\widetilde{R}-c}{c}\right)}{\Delta\widetilde{X}-\Delta\widetilde{R}}\left(\Delta\widetilde{R} - \Delta\widetilde{X}\right)$$

$$\Leftrightarrow \frac{R^H-2X^L}{\Delta\widetilde{X}-\Delta\widetilde{R}-c} < \left(R^H - 2X^L\right)\frac{\ln\left(\frac{p}{1-p}\frac{\Delta\widetilde{X}-\Delta\widetilde{R}-c}{c}\right)}{\Delta\widetilde{X}-\Delta\widetilde{R}}$$

which holds as seen in the proof of Proposition 3.

Hence, as $G\left(\frac{\Delta\widetilde{R}}{\Delta\widetilde{X}}\right) > H(1-\delta)$[18] and $e_d^* > e_e^*$ if $\frac{\Delta\widetilde{R}}{\Delta\widetilde{X}} = 1-\delta$, one can infer that $\frac{\Delta\widetilde{R}^*}{\Delta\widetilde{X}} > 1-\delta^*$ in equilibrium. Next, note that, even if $e_d = e_e$, then:

[18]This is because, if $\frac{\Delta\widetilde{R}}{\Delta\widetilde{X}} = 1-\delta$ and thus $e_d^* > e_e^*$, then $e_d^*\left((1-\delta)\Delta\widetilde{X} + X^L\right) + \left(1-e_d^*\right)X^L = (1-\delta)e_d^*\left(X^H - X^L\right) + X^L > (1-\delta)e_e^*\left(X^H - X^L\right) + (1-\delta)X^L = (1-\delta)\left(e_e^* X^H + \left(1-e_e^*\right)X^L\right) \Rightarrow G\left(\frac{\Delta\widetilde{R}}{\Delta\widetilde{X}}\right) > H(1-\delta)$.

$$e_d\left(R^{H*}-X^L\right)=e_e\left(R^{H*}-X^L\right)>e_e\left((1-\delta^*)X^H-X^L\right)\geq$$
$$(1-\delta^*)e_e\left(X^H-X^L\right)-\delta^*X^L\Rightarrow G\left(\frac{\Delta\widetilde{R}^*}{\Delta\widetilde{X}}\right)>H\left(1-\delta^*\right)\Big|_{e_d=e_e}.$$

Therefore, it must hold that $e_d^* < e_e^* < e_{fb}^*$ in equilibrium, and the borrower's utility is increasing in e^*, as shown in the proof of Proposition 3. ■