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A COMPETITIVE ANALYSIS OF RURAL CREDIT:
STATE-CONTINGENT LOANS IN NORTHERN NIGERIA

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Abstract

In much recent theoretical literature, the problems of moral hazard and adverse selection are assumed to be decisive for the organization of agrarian institutions. In contrast, it is found that credit transactions in northern Nigeria take advantage of the free flow of information within rural communities. Information asymmetries are important, and their institutional consequences - the use of collateral and interlinked contracts - are absent. Credit transactions play a direct role in pooling risk between households through the use of contracts in which the repayment owed by the borrower depends on the realization of random production shocks by both the borrower and the lender.

The paper presents a model which explores the general equilibrium consequences of contingent contracts in a dynamic setting. The prices required to support a Pareto optimum are derived, yielding predicted transaction flows over time. Estimates of the model indicate that quantitatively important state - contingent payments are embedded in these loan transactions. Further testing indicates that a fully efficient risk-pooling equilibrium is not achieved through these transactions.

The research is based on a year long survey in Zaria, Nigeria conducted by the author.

KEY WORDS: Rural Credit, General Equilibrium Modeling, Risk

1. The Theoretical and Geographical Setting.¹

People who live in the rural areas of poor countries often must cope not only with severe poverty but with extremely variable incomes. In uncertain environments which lack complete insurance markets, credit transactions take on a special role by allowing people to smooth income shocks over time.² This paper provides a competitive general equilibrium analysis of the role played by the rural credit markets of northern Nigeria in facilitating the efforts of households to cope with risk.

The usual assumption in the literature on rural credit in poor countries is that simple competitive models are irrelevant to the study of these markets. Moral hazard and adverse selection are considered to be especially prevalent in credit transactions, therefore, credit markets are commonly thought to incorporate organizational features that serve to mitigate the problems caused by these information asymmetries. A number of theoretical papers have explored the implications of imperfect information for contractual forms in credit markets in low-income rural settings, and a set of specific institutional features has been hypothesized to be prevalent in these

¹I received valuable advice from the members and chairman of the Department of Agricultural Economics and Rural Sociology, Ahmadu Bello University, where I was a visiting Research Fellow. Adex Adisa, Comfort Amos, Mary Arokoyo, Florence Bako, Christiana Chindo, Abdu Haruna, Haruna Mohammad, Ayuba Randa, and Yohanna Tanko provided able and dedicated research assistance. I am grateful to Richard Blundell, Robert Evenson, Karla Hoff, Barbara O'Brien, Dayo Phillip, Gustav Ranis, T.N. Srinivasan, John Strauss, Duncan Thomas and David Weiman as well as to participants at number of seminars for their comments and advice. This material is based upon work supported by the National Science Foundation under Grant No. SES-8618906. I also acknowledge financial support from the Social Science Research Council, the Fulbright-Hays Research Abroad program, the Sloan Foundation and the Yale Center for International and Area Studies.

²Eswaran and Kotwal (1989) provide a recent theoretical treatment. Rosenzweig (1990) examines the insurance role of credit transactions in India.

markets.³ In contrast to the assumptions of this literature, I argue in earlier work (Udry [1990]) that information asymmetries between borrowers and lenders in northern Nigeria are unimportant.⁴ Neither formal sector lending institutions nor specialized private moneylenders participate in the credit market. There is widespread participation on both sides of the credit market in these villages; over the course of the survey year 75 percent of households made loans and 65 percent of households borrowed (50 percent participated as both lenders and borrowers). The transactions occurred between people who know each other well; 97 percent of the loans (weighted by value) were between neighbors or between relatives. For 82 percent of loans, survey participants were able to provide an accounting of activities on the farms of those from whom they borrowed, or to whom they lent (Udry [1990, p. 259]). Common institutional adaptations to information asymmetries are not found in this credit market. There is no evidence of contractual interlinkages involving

³See Bell (1988), Bardhan (1989) and Udry (1991b) for comprehensive bibliographies. Two organizational features - collateral use and market interlinkages - have received particular attention.

⁴This research program is based on a survey of 200 households in 4 villages near the city of Zaria that I undertook from February 1988 to February 1989. The survey consisted of monthly interviews with each of the household heads and (separately) his wives. The questionnaires were designed to yield a complete picture of each household's asset and debt position; an account of its credit, labor, product, asset, and asset-rental transactions over the previous month; and a range of demographic and background data. For details on the study area and survey methodology, see Udry (1991b). Summary data from the survey are presented in Table 1.

The are in the heart of one of the most dynamic and promising agricultural regions of Africa. Rain-fed agriculture predominates, though there is also dry-season irrigated farming on lowlands bordering streams (fadama). 73 percent of the sample households produce vegetables and non-food cash crops for the market and 53 percent of all labor used on sample household farms was wage labor. 95 percent of cultivated land was treated with chemical fertilizers. A large variety of nonagricultural occupations exists, including small-scale industry, trading, and the provision of transport services, but every household in the research villages operates a farm.

loans, and only 3 percent of loans (by value) are backed by collateral (Udry [1990, section III]). There is little direct evidence, therefore, of any important deviation from the complete information assumption of the standard competitive framework. This simple framework, therefore, serves as the starting point of this paper.

The free flow of information within these rural communities allows credit contracts to play a direct role in insuring against risk. The survey data indicate that the repayment owed on a loan depends upon random shocks received by both borrower and lender over the period during which the loan is outstanding, permitting these households to directly pool their idiosyncratic risk. Table 2 provides an example of the evidence presented in Udry (1990) in support of the hypothesis of state-contingent contracting. Realized interest rates are lower and repayment periods are longer for debtor households who have experienced adverse shocks (Table 2, panel A). This observation is consistent with conventional credit contracts because those who experience adverse shocks are more likely to default. The evidence that repayments respond not only to the entire circumstances of the debtor household, but also to those of the creditor household (Table 2, panel B), however, is not consistent with conventional models. The flexibility of these contractual forms allows for more efficient risk sharing between the debtor and the creditor than is possible with conventional fixed interest contracts. Furthermore, this flexibility permits credit transactions to conform to the Islamic prohibition of fixed interest rates.⁵

⁵Investment income is prohibited if the investor does not share in the risks of the enterprise. Hence an equity investment is legal, while lending with a fixed interest rate is not. Risk must be shared in proportion to the capital contributed to an enterprise, thus not any state-contingent credit contract is legal under Shari'a law. Fixed repayment periods are also prohibited: 'And if

In section 2 I develop a competitive general equilibrium model of state-contingent loan contracting in order to formally test the hypothesis that these credit transactions include state-contingent repayments. In section 3 I present estimates which confirm the quantitative importance (as well as statistical significance) of state-contingent payments that flow toward households which receive unexpected adverse production shocks.

The apparent importance of direct risk pooling through state-contingent loan repayments raises the possibility that the allocation of resources within these villages approximates Pareto efficiency. If these loan transactions mimic a complete set of competitive insurance markets, then it is not necessary to understand the particular contractual arrangements in these credit markets in order to discern the economic impact of the loans. On the other hand, if Pareto efficiency is not achieved through these loan transactions, then a more detailed investigation of the institutional and informational setting of these transactions becomes imperative. Therefore, in section 3 I present a formal test of the hypothesis that full risk pooling is achieved through these transactions. The results indicate that full risk pooling is not achieved in these four northern Nigerian villages. A number of studies have recently explored the complete markets hypothesis in other contexts. Townsend (1991) shows that there is a high degree of co-movement in individual (age-sex adjusted) consumption across households within villages covered by the ICRISAT Indian survey. He presents some evidence, however, that a fully Pareto efficient allocation is not achieved in the Indian villages. Lim (1990), using data from the same ICRISAT survey, tests the

the debtor is in difficulty, then [there should be] postponement to a time of ease' (Koran 2:280).

hypothesis of full Pareto efficiency against the alternative 'permanent income' hypothesis that each household separately smooths its income shocks over time. He concludes that the data correspond more closely to full Pareto efficiency than to the permanent income hypothesis. The complete markets hypothesis has also been tested with data from the U.S.. Altonji, Hayashi and Kotlikoff (1991), Altug and Miller (1990), Mace (1989), and Cochrane (1989) provide examples of empirical tests of implications of Pareto efficiency. Only Altug and Miller (1990) are unable to reject the (stringent) standard that a complete risk pooling, Pareto efficient allocation of resources is achieved in the U.S..

2. A Competitive Model.

Consider a competitive model of the credit market. This model embraces the notion that information flows freely within the community and that loan contracts are state-contingent. It does so at the cost of treating these personalized contracts in a highly abstract manner, in that it views the household as a price-taker on the loan market. Detailed consideration of the institutional details of the transactions is the subject of Udry (1991a). The focus of this section will be the general equilibrium and efficiency consequences of the availability of state-contingent loan contracting.

A wide variety of financial instruments could be devised to pool risks in a village community. I will focus only on contracts which are taken in one period and discharged in the next. This one-period-ahead contracting corresponds to the transactions observed during the fieldwork, in which loans are taken just before (or early in) the planting season and repaid after harvest.

A. Loan Contacts as State Contingent Securities.

Consider a world with only one (non-storable) good (Y) and N households. Let there be T+1 periods, indexed by $t \in [0, T]$. There are S states of nature indexed by s, each with an objective, constant and commonly known probability of occurrence π^s . This probability is stationary and independent of the history of realized states.⁶ There is no production; each household receives each period an endowment of the good which depends upon the realized state of nature.⁷ Denote these (positive) endowments by $y_{i,s}$ for $1 \leq i \leq N$ and $1 \leq s \leq S$. The endowment of each household depends only on the state of nature, not on the period.

Each bilateral loan contract is interpreted as a collection of contingent securities, where each security R^s entitles the owner to one unit of the good Y in the next period if state s is realized. These contracts are perfectly enforced; default is assumed to be impossible. If default were permitted, under general conditions some households would demand an infinitely large loan at any interest rate, with certain default in the next period. The no default assumption can be dropped and the existence of equilibrium maintained only if other special assumptions are made. Exogenous limits on the demand for credit by a household could be posited.⁸ Global restrictions could be placed on utility functions so that the cost of a certain default next period outweighs the benefit of even infinitely large borrowing this

⁶This assumption is made to simplify notation. Some forms of autocorrelation are permitted below.

⁷Production and storage are permitted in the appendix.

⁸This is the strategy of Srivastava (1989), and would be adopted by Kletzer to correct a difficulty in the interest rate equilibrium of Kletzer (1984) (personal communication).

period. Finally, the assumption of price-taking behavior could be dropped, thereby introducing strategic behavior by borrowers and lenders who negotiate over contractual terms and the size of the loan. It is this later approach that I adopt in Udry (1991a).

If the available securities span the state space, the competitive equilibrium will be Pareto efficient. The first task, therefore, is to describe the relevant characteristics of efficient allocations. Let $h_t = \{s_1, s_2, \dots, s_t\}$ be the history of states realized from period 1 through period t . Let $N(s|h_t)$ be the count of occurrences of state s in history h_t over the t periods. Then the probability of any history h_t is

$$1. \quad \pi(h_t) = \prod_{s=1}^S (\pi^s)^{N(s|h_t)}$$

Let $c_{i,s,t}(h_{t-1})$ be the realized consumption of individual i if state s occurs in period t after history h_{t-1} , and c_{i0} by the consumption of household i in the initial period. The separable von Neumann-Morgenstern utility of household i is:

$$2. \quad U(c_{i0}) + \sum_{t=1}^T \beta^t \left[\sum_{h_{t-1} \in H_{t-1}} \pi(h_{t-1}) \left[\sum_{s=1}^S \pi^s U(c_{i,s,t}(h_{t-1})) \right] \right]$$

where H_{t-1} is the set of all possible histories that may be realized up to period $t-1$.⁹ The innermost summation is the undiscounted expected utility in period t given that history h_{t-1} has occurred. $\pi(h_{t-1})$ is the probability that history h_{t-1} occurs, and the intermediate sum is over all possible histories through period $t-1$. The outermost summation finds the value of the expected

⁹This specification of the utility function is required only for the comparative static analysis. All of the other results below follow as long as the utility function is separable in time.

utility stream by discounting over the T periods. In the interest of parsimony in notation, utility functions are assumed to be identical across all households. $U()$ is assumed to be increasing, strictly concave and twice continuously differentiable over $\mathbb{R}^{++}$. Finally, $U'(x) \rightarrow +\infty$ as $x \rightarrow 0^+$.

Certain familiar results follow immediately. In a Pareto efficient allocation, $c_{i,s,t}(h_{t-1}) = c_{i,s,t}$ for all $h_{t-1} \in H_{t-1}$. That is, consumption is independent of history. There is no growth in the economy, therefore $c_{i,s,t} = c_{i,s}$ for all $t > 0$, i , and s . That is, consumption is independent of period. Finally, each household's consumption in any state s is a non-decreasing function of the total community resources available in that state. Transient changes in income will be fully pooled at the community level, so no risk diversification will occur within the household. These immediate conclusions are patently false¹⁰, but the idea of state-contingent loan contracts with multiple partners remains compelling. My strategy is to use these efficiency results to examine the consequences of fully flexible contingent markets and then to introduce restrictions that modify the fully Pareto optimal, risk pooling outcome of the initial model.

The notational convention to be used will be that subscripts refer to states realized in the current period, while superscripts refer to states which may occur in the next period. So let $R_{s,t}^{s'}(h_{t-1})$ be the security purchased in state s of period t after history h_{t-1} for payment in state s' of period $t+1$. Let $q_{s,t}^{s'}(h_{t-1})$ be the price of that security on the competitive market.

The household's preferences have been described in equation 2. The good is not storable, so the budget constraints are:

¹⁰As confirmed, for example, by recent work by Rosenzweig and Stark (1989).

3. $c_0 = Y_s - \sum_{s'} q_{s,0}^{s'} \times R_{s,0}^{s'}$ for $t=0$. s is the state realized in period 0. Y_s is income when state s is realized. Initial period consumption is the income received in the state realized in period zero minus the net amount spent on purchasing securities for the various states that may occur in period 1. This amount may be positive or negative because borrowing (short selling) is permitted.

4. $c_{s,t}(h_{t-1}) = Y_s + R_{s^*,t-1}^s(h_{t-2}) - \sum_{s'} q_{s,t}^{s'}(h_{t-1}) \times R_{s,t}^{s'}(h_{t-1})$ for $0 < t < T$, for all s . s^* is the state that was realized in period $t-1$. Consumption is equal to the income received in the state s realized in that period, plus the number of bonds (which may be negative) purchased in the previous period for payment if state s occurs in period t , minus the net amount spent on purchasing securities for the various states that may occur in the next period.

5. $c_{s,T}(h_{T-1}) = Y_s + R_{s^*,T-1}^s(h_{T-2})$ for $t=T$, for all s . s^* is the state realized in period $T-1$. In the final period, consumption equals the income received in that period plus the number of bonds purchased in period $T-1$ for payment if state s occurs in the final period.

The household maximizes (2) given (1) and (3-5), and calculates its demands for contingent securities for all possible histories h_T . This assumes that the household knows with certainty the prices that will prevail at time t after any history h_t . The problem as written is equivalent to the sequential programming problem in which the household re-optimizes each period as the state is revealed.

C. Efficiency of Equilibrium and the Behavior of Prices.

If the assumption that the contingent securities span the state space is valid, then markets are complete in this model and the competitive equilibrium

will be Pareto efficient. After substituting necessary conditions for efficiency into the first order conditions of the household's optimization program, we find that the prices required to support the efficient equilibrium must satisfy:

$$6. \frac{q_{s,t}^i(h_{t-1})}{q_{s,t}^j(h_{t-1})} = \frac{\pi^i}{\pi^j} \cdot \frac{U'(c_{i,t+1})}{U'(c_{j,t+1})} = \frac{\pi^i}{\pi^j} \cdot \frac{U'(c_i)}{U'(c_j)} \quad \begin{matrix} i,j,s \in S, \\ \text{for all } t. \end{matrix}$$

So the relative prices of the different securities are constant across time.

Thus, we can find a scalar τ_t for each $s, s' \in S$ such that

$$7. q_{s,t}^{s'}(h_{t-1}) = \tau_t \times q^{s'} \quad \text{where } \tau_t > 0 \text{ and } \sum_{s'} q^{s'} = 1.$$

This normalization is arbitrary, but has the advantage of excluding the possibility of using a security with a zero price as numeraire. Security prices are determined by the time-, history-, and state-independent set of normalized relative prices $q^{s'}$ and by the scaling factor τ_t . After imposing the constraint that in any Pareto Optimum consumption will be time- and history-independent we find:

$$8. \frac{q_{s^*,t}^{s'}(h_{t-1})}{q_{s,0}^{s'}} = \frac{U'(c_{s^*,t}(h_{t-1}))}{U'(c_0)}, \text{ for all } s, s', s^*, 1 \leq t \leq T, \text{ where } s \text{ is the}$$

state realized in period 0, s^* is the state realized in period t , and s' are the states that may occur in period $t+1$. Therefore, given the initial period state, the scaling factor τ in any period t will depend only on $c_{s^*,t}(h_{t-1}) = c_{s^*,t}$, the realized consumption in that period, which in turn depends only on that state realized in that period. The higher community income and therefore consumption in that state, the higher will be τ_t .

A higher τ_t implies that borrowing in period t for repayment in period $t+1$ is less expensive. In return for a promise of a given set of repayments

in period $t+1$, $R_{s,t}^s(h_{t-1})$, the borrower in period t receives $r_t \sum q_s \times R_{s,t}^s(h_{t-1})$. A higher r means that more is received in period t for given repayments in period $t+1$ - cheaper credit. Thus in a state in which community income and individual households' consumption is high, credit is cheap. As community income and each households' consumption declines, credit becomes more expensive, choking off the potential increase in excess demand for credit in this closed market, and thus preserving equilibrium.

D. Time Pattern of Securities Purchases.

Now consider the situation in period $T-1$. From the budget constraint and efficiency we know that for all histories h_{T-1} , $c_{s,T}(h_{T-1}) = Y_s + R_{s^*,T-1}^s(h_{T-2}) = c_s$ for all s . So $R_{s^*,T-1}^s(h_{T-2}) = R_{T-1}^s$ regardless of history h_{T-2} or the state s^* realized in period $T-1$. So the security purchased in period $T-1$ for payment in period T if state s occurs is R_{T-1}^s , regardless of the history of states realized up to and including period $T-1$.

The sum $\sum(q^s \times R_{T-1}^s)$ (summed over the states s) may be positive or negative; suppose it is positive (the household is a lender). Depending upon the state realized in period $T-1$, the prices q will be scaled by $r_{T-1} = f(s_{T-1})$. The amount lent will be $r_{T-1} \sum(q^s \times R_{T-1}^s) > 0$. This amount depends only upon the state realized in period $T-1$; it is independent of history h_{T-2} . Thus in any state s' of period $T-1$, after payment of $R_{s^*,T-2}^s(h_{T-3})$ (purchased in state s^* of period $T-2$ after history h_{T-3} for payment if state s' occurs in period $T-1$), the household must have $c_{s'} + r_{T-1} \sum(q^s \times R_{T-1}^s)$ in order to purchase the required securities R_T^s and still consume $c_{s'}$. That is,

$$9. \quad Y_{s'} + R_{s^*,T-2}^{s'}(h_{T-3}) = c_{s'} + r_{T-1} \sum_s (q^s \times R_{T-1}^s) = I_{T-1}^{s'} \quad \text{for all } s'.$$

Therefore, regardless of the state in period $T-2$, the household must purchase securities R_{T-2}^s sufficient to ensure that in period $T-1$ it will have funds enough to consume along the Pareto efficient path and purchase the securities required for period T . The securities R_{T-2} , purchased in period $T-2$, are independent of the history of states realized up to and including period $T-2$. This demonstration of history-independence can obviously be repeated for R_{T-3}^s , etc...

A definite relationship exists between c , I_{T-1} , I_{T-2} , and so on. If $\Sigma(q^s \times R_{T-1}^s) > 0$, as we assumed above, then $I_{T-1} > c$ in each element. This implies that $R_{T-2}^s > R_{T-1}$ in each element, which in turn implies $\Sigma(q^s \times R_{T-2}^s) > \Sigma(q^s \times R_{T-1}^s)$. So, $I_{T-2} > I_{T-1}$, and so on. Starting from period $T-k$ moving towards period T , we see that in each realized state the household becomes a smaller and smaller lender. The largest lending occurs in period 0 and is equal to $Y_0 - c^0$, where c^0 is the component of the c vector that corresponds to the state realized in period 0. Alternatively, if $Y_0 - c^0 < 0$, the household will be a borrower in all periods, with its largest borrowing in period 0.

This analysis can be summarized in a simple diagram (Fig 1). Total community income (Y) may be different in the different states. In this figure I have indexed the states by total community income in that state. The vector c here becomes a line, describing individual income as a function of the state (s). The diagram is drawn for a world of four periods. In period 3 the household purchases securities R_3^s such that when the state is revealed in period 4, it will pay (or receive) just enough to consume on c . As drawn, the state realized in period 4 has community income Y_4 and household income Y_4 , so the household receives the payment R_3^{s4} . As drawn, the sum $\Sigma q^s \times R_3^s$ is positive. The total cost of purchasing securities R_3 (the amount lent, which

is equal to $\tau(s)\Sigma q^s \times R^s_3$) will vary depending on the state realized in period 3. $\tau(s)$ will be low in states in which consumption is low (credit is expensive) and high in states of high consumption. The gap between I_{T-1} and c equals the amount $\tau(s)\Sigma q^s \times R^s_3$. The securities R_2 (which the household purchases in period 2 for payment in period 3) must be such that after the state is revealed in period 3, the household will pay (or receive) an amount that will put it on the line I_{T-1} . The household will then have the resources to purchase the securities R_3 and still consume on c . As drawn, the state in period 3 has community income Y_3 and household income Y_3 , so the household makes the payment R_2^{s3} . The backward induction continues until at period zero the household spends $\tau(s)\Sigma q^s \times R^s_0$ to purchase the first period securities and consume on c .

The model implies that the securities purchased in any period t are independent of the state realized in that or any previous period. The cost of the securities purchased in period t will depend, however, on τ_t , which in turn depends on aggregate community income in period t . Furthermore, over time the households regress toward zero net lending. This later finding may be more difficult to verify empirically than it was to show theoretically. As the number of periods T is increased, the period-to-period change in net lending is reduced.¹¹ Other factors are also changing over time. In particular, if the age of a household head has any effect on his productivity, it may be difficult to separate the effects of progressing age from movement across periods. This point is reinforced by the fact that the number of

¹¹In a Barro-Becker model of altruism across generations trading will effectively continue forever as long as bequests are positive. In such a situation, T is infinite and this derivative is zero.

periods of loan transactions remaining to a household is uncertain, and the best predictor of that number may be the age of the household head.

The model can easily be modified to include agricultural production on a fixed amount of land. The optimality results remain and community income is still pooled. It can be shown (appendix A) that investment in agricultural production is directed to plots on which output is less correlated with overall community income and that this diversification is carried out at the community level, not the household level. If there is more than one alternative asset (e.g., different plots of land), it can again be shown that investment is guided by the goal of reducing the variance of community income so no diversification occurs at the household level.

E. Transactions Costs

A significant number of households neither lend nor borrow (42 households). This fact does not accord well with a theoretical model based on a smoothly operating competitive market with no default. I will therefore call upon the *deus ex machina* of transactions costs. If there is a cost to entry into the securities market in any period (which perhaps increases with transaction size), then there is a positive probability that a zero loan size is optimal. Justification for allowing for the possibility of transactions costs can be provided by assuming that some effort must be expended to observe the realized state or to enforce the no-default provision of these contracts.

Inflows to and outflows from each household must now be distinguished, in order to account properly for the transactions costs that intervene between the transfer from one household and that received by another. Let $I_{i,s,t}(h_{t-1})$ be the gross transfer to household i (inflow) if state s occurs in period t after history (h_{t-1}) and $O_{i,s,t}(h_{t-1})$ be the gross transfer from household i

(outflow) if state s occurs in period t after history (h_{t-1}) . The form of transactions costs used here is that of Samuelson (1954) - of each unit of the good that is given up by a household, only a fraction k reaches the recipient household.

Any Pareto Optimum can be generated by maximizing an appropriately weighted sum of the utility functions (eq. 2) of the N households subject to the resource constraints:

$$\begin{aligned} 10. \quad c_{j0} &= Y_{j,s} - O_{j,s,0} + I_{j,s,0} \\ 11. \quad c_{j,s,t}(h_{t-1}) &= Y_{j,s} - O_{j,s,t}(h_{t-1}) \\ 12. \quad I_{j,s,t}(h_{t-1}) &\geq 0, \quad O_{j,s,t}(h_{t-1}) \geq 0 \\ 13. \quad \sum_{j=1}^N I_{j,s,t}(h_{t-1}) &\leq k \sum_{j=1}^N O_{j,s,t}(h_{t-1}) \end{aligned}$$

with respect to $I_{j,s,t}(h_{t-1})$, $O_{j,s,t}(h_{t-1})$ for all s, j, t and $h_T \in H_T$.

Transactions costs enter through constraint 13. With $0 < k < 1$, it is trivial to show that no household will both receive inflows and give up outflows in any single state after a particular history in the efficient allocation.

The first order conditions imply that all households with an outflow of the good in state s , in period t , history h_{t-1} have the same weighted marginal utility of consumption. The weights are the λ_i , the weight of their utility in the Pareto program:

$$14. \quad \lambda_i U'(c_{i,s,t}(h_{t-1})) = \frac{\lambda_{s,t}(h_{t-1})}{\pi(h_T) \beta^t} \cdot k, \text{ for all } i \text{ s.t. } O_{i,s,t}(h_{t-1}) > 0.$$

Similarly,

$$15. \quad \lambda_j U'(c_{j,s,t}(h_{t-1})) = \frac{\lambda_{s,t}(h_{t-1})}{\pi(h_T) \beta^t}, \text{ for all } j \text{ s.t. } I_{j,s,t}(h_{t-1}) > 0.$$

Finally, the first order conditions with the non-negativity constraints binding imply that any household h which does not receive any inflow, or give

up any outflow of the good must have a weighted marginal utility of consumption that falls within the bounds set by 14 and 15:

$$16. k\lambda_i U'(c_{i,s,t}(h_{t-1})) < \lambda_h U'(Y_{h,s,t}(h_{t-1})) < \frac{1}{K} \lambda_j U'(c_{j,s,t}(h_{t-1}))$$

for all i such that $O_{i,s,t}(h_{t-1}) > 0$, j such that $I_{j,s,t}(h_{t-1}) > 0$, and h such that $O_{h,s,t}(h_{t-1}) = I_{h,s,t}(h_{t-1}) = 0$. As $k \rightarrow 1$, the efficient allocation approaches that achieved with no transactions costs. The optimal allocation in the case of two households can be understood with reference to figure 2. The vertical axis measures the income and consumption of household i ; the horizontal axis measures the same for household j . Suppose $O_{it}^s(h_{t-1}) > 0$.

From 13, $I_{jt}^s(h_{t-1}) = k \cdot O_{it}^s(h_{t-1})$. From 14 and 15, we find $\frac{U'(c_{it}^s(h_{t-1}))}{U'(c_{jt}^s(h_{t-1}))} = \frac{k\lambda_j}{\lambda_i}$.

In figure 2, OA is the locus of (c_j, c_i) such that this condition is

satisfied. Similarly, suppose $I_{it}^s(h_{t-1}) > 0$. From 13, $k \cdot O_{jt}^s(h_{t-1}) =$

$I_{it}^s(h_{t-1})$. From 14 and 15, $\frac{U'(c_{it}^s(h_{t-1}))}{U'(c_{jt}^s(h_{t-1}))} = \frac{\lambda_j}{k\lambda_i}$. In figure 2, OB is the locus of (c_j, c_i) such that this condition is satisfied. If $O_{it}^s(h_{t-1}) = I_{it}^s(h_{t-1}) =$

$O_{jt}^s(h_{t-1}) = I_{jt}^s(h_{t-1}) = 0$, then $\frac{k\lambda_j}{\lambda_i} < \frac{U'(Y_1^s)}{U'(Y_j^s)} < \frac{\lambda_j}{k\lambda_i}$. When the state is such that the point (Y_j^s, Y_i^s) falls between OA and OB, then no transfer takes place. If (Y_j^s, Y_i^s) falls above OA (as at point 1), then i transfers to j with (only k of each unit reaching j) until the locus OA is reached (as at point 2). If (Y_j^s, Y_i^s) falls below OB (as at point 3), then j transfers to i with (only k of each unit reaching i) until the locus OB is reached (as at point 4).

It can be seen, therefore, that the efficient consumption streams and transfers can be determined with knowledge of the distribution of income Y , the transactions cost k , and the social weights λ_i . The period t and the

history of realized states h_{t-1} are irrelevant to the determination of efficient transfers.

Now consider competitive equilibrium with these transactions costs. Define $B_{s,t}^{s'}(h_{t-1})$ as the purchase of a security in state s of period t after history h_{t-1} for payment in period $t+1$ if state s' occurs. $p_{s,t}^{s'}(h_{t-1})$ is the price an agent pays to buy the security. $S_{s,t}^{s'}(h_{t-1})$ is the sale of a security in state s of period t after history h_{t-1} for payment in period $t+1$ if state s' occurs, $q_{s,t}^{s'}(h_{t-1})$ is the price received by the agent for the sale. The household's problem is to choose $B_{s,t}^{s'}(h_{t-1})$ and $S_{s,t}^{s'}(h_{t-1})$ for all s, t , and $h_t \in H_t$ to maximize (2) subject to non-negativity on B and S and

$$17. c_0 = Y_s + \sum_{s'} [q_{s,0}^{s'} S_{s,0}^{s'} - p_{s,0}^{s'} B_{s,0}^{s'}],$$

$$18. c_{s,t}(h_{t-1}) = Y_s + B_{s,t-1}^{s^*}(h_{t-2}) - S_{s,t-1}^{s^*}(h_{t-2}) \\ + \sum_{s'} [q_{s,t}^{s'} S_{s,t}^{s'}(h_{t-1}) - p_{s,t}^{s'} B_{s,t}^{s'}(h_{t-1})], \text{ and}$$

$$19. c_{s,T}(h_{T-1}) = Y_s + B_{s,T-1}^{s^*}(h_{T-2}) - S_{s,T-1}^{s^*}(h_{T-2})$$

for $0 < t < T$, $s, s^* \in S$. s^* is the state realized in period $t-1$ after history h_{t-1} ; s is the state realized in period t . Thus $\sum [q_{s,t}^{s'}(h_{t-1}) \times S_{s,t}^{s'}(h_{t-1}) - p_{s,t}^{s'}(h_{t-1}) \times B_{s,t}^{s'}(h_{t-1})]$ (summing over the states which may occur next period, s') is the net borrowing of the household in state s of period t after history h_t , and $B_{s,t}^{s'}(h_{t-1}) - S_{s,t}^{s'}(h_{t-1})$ is the net repayments to the household if s' occurs in period $t+1$. Competition in the transfer of securities between households ensures that $q_{s,t}^{s'}(h_{t-1}) = k \cdot p_{s,t}^{s'}(h_{t-1})$ for all s, s', t and $h_{t-1} \in H_{t-1}$, reflecting the constant returns to scale transfer technology. No profits are made by agents engaged in transferring securities, so such activity does not affect the budget constraints 17-19. As in the model without transactions costs, the contingent securities span the state space. The wedge between the buying and

selling prices of the securities induces households to internalize the transactions costs and the competitive equilibrium is Pareto efficient.

3. An Econometric Model.

In this section I present an econometric model of loan transactions in rural northern Nigeria. Each loan contract observed in the data is modeled as a collection of state contingent securities. The variables of interest are the net borrowing of the household over a specified period (B), and the net repayment of those loans (REP). The convention observed in the empirical work is that all amounts flowing to a sample household are positive. The net borrowing observed in the data in state s of period t after history h_{t-1} is the net revenue from the securities sold, $\sum [q_{s,t}^s(h_{t-1}) \times S_{s,t}^s(h_{t-1}) - p_{s,t}^s(h_{t-1}) B_{s,t}^s(h_{t-1})] = B$. The net repayments to the household if state s' is realized in period $t+1$ are $B_{s,t}^s(h_{t-1}) - S_{s,t}^s(h_{t-1}) = \text{REP}$. The solution to the household problem implicitly defines a net demand function $\text{REP}(\cdot)$ for a particular security, and therefore also a net supply function of all securities $B(\cdot)$. Net borrowing of household i B_i will be a function of a vector of exogenous shifters X_i , of the number of periods the household has been involved in the market P_i and of a random disturbance ν_{1i} . Net repayments to household i , REP_i , will be a function of the same vector of exogenous shifters X_i , of P_i , of a random disturbance ν_{2i} , and of idiosyncratic production shocks received by the household (S_i). I assume that the random disturbances are jointly normally distributed.

The choice of explanatory variables to be included in the vector X_i will be discussed in the following section, but it should be noted that X_i will include village dummy variables to capture the effect of aggregate village

production shocks on the cost of credit (the price level τ_t of the securities).

P_1 will be approximated by the number of years since the household head's first married, or since he moved to his current village, whichever is smaller. This assumes that households enter the credit market as soon as they are formed. As noted above, net lending regresses toward zero over time. Thus for a net lender, $\delta(B^{s'} - S^{s'})/\delta P = \delta REP/\delta P < 0$ for all s (> 0 for a net borrower). The derivative of repayments with respect to period for net borrowers has the opposite sign as the same derivative for net lenders. The switch in the sign of these derivatives depending upon the borrowing/lending status of the household will require switching regression methods in the estimation. Recall however that the derivative will be close to zero if T is large. For both net borrowers and net lenders the derivative of net borrowing with respect to period has the opposite sign as the derivative of repayments with respect to period.

S_1 , the indicator of the random shock received by the household after the initial loans have been made, is an index of self-reported events on the plots farmed by the household. The index is a weighted average of the number of these negative events (examples: flooding, lodging, animal invasions) on each plot and the weights are the relative sizes of each plot. The index is broken down by upland and lowland plots, and is the same as that used in the construction of Table 2. Its use depends upon the assumption that the events used in its construction are observable to the village community and exogenous to the behavior of the agents. Further, the deviation of the household's index from the village mean index must be serially uncorrelated. The first assumption is strongly supported by the evidence presented Udry (1990). The

second assumption is more problematic, for while some events which enter the index are plausibly exogenous (e.g. animal invasions), others are not. The probability of lodging or flooding, for example, can be influenced by farming practices. However, if farming activities themselves are observable to the community the moral hazard otherwise arising from the endogeneity of these events can be controlled. The third assumption corresponds to the stationarity assumption. Village-level shocks can be correlated over time without changing these results, for they influence only the price level r_t , and will be eliminated through use of the village dummy variables. The deviation of individual shocks from the village mean shock, however, must be serially uncorrelated in order to support the equilibrium derived here.

Linear approximations to net borrowing B and net repayments REP are estimated. The net borrowing equation is augmented with a friction model, which allows for a positive probability of zero loan size. The use of Samuelson "iceberg" transactions costs implies that the particular form of friction is that of Rosett (1959).

Once the possibility of non-participation in the market is acknowledged, estimation of the repayment equation must take into account the selection bias thereby induced. In addition, as shown above, the derivatives of B and REP with respect to period P change signs depending on net borrowing/lending status. This necessitates the use of switching regression methods in the estimation of both B and REP . The model is:

$$\begin{aligned}
 20. \quad & a. \quad B = X\alpha + \alpha_B P + \nu_1 && \text{if } X\alpha + \alpha_B P + \nu_1 > 0 \\
 & \quad \text{or} \\
 & \quad b. \quad B = X\alpha + \alpha_L P + \nu_1 - F && \text{if } X\alpha + \alpha_L P + \nu_1 - F < 0 \\
 & \quad \quad \text{else} \\
 & \quad c. \quad B = 0
 \end{aligned}$$

$$21. \quad \tilde{REP} = X\beta + (1-I)\beta_L P + I\beta_B P + S\gamma + \nu_2$$

where $I=1$ if $B > 0$, $I=0$ if $B < 0$

$$22. \quad REP = \begin{cases} 0 & \text{if } B = 0 \\ \tilde{REP} & \text{if } B \neq 0. \end{cases}$$

This model may suffer from incoherence because equations 20a and 20b can be true simultaneously. This is unlikely to be true in practice because it requires the effect of P on net borrowing to be so different when the household borrows than when it lends that the household switches from demanding loans to supplying loans. To lead to incoherence this switch must be large enough to overcome the friction effect F . I have made the *ad hoc* assumption that the decision is made sequentially, as written, in order to eliminate the theoretical possibility of incoherence. Alternatively, a sufficient condition for coherence is $\alpha_B > \alpha_L$ and $F > 0$.

No variables are available which can serve to identify the friction coefficient F separately from the net borrowing equation. This coefficient is identified, therefore, through the nonlinearity of the model and distributional assumptions. The likelihood function is presented in the appendix B.

A. Data Definitions.

Table 3 lists the variables used. The dependent variables are calculated from data on all loans taken or extended by a sample household for a single main cropping period. The loans included in this analysis are those initially extended during the period from the harvest before the survey began until the middle of the main cropping season during the survey year (September). By September, early crops have been harvested and some loan repayments begun. Net borrowing B_1 is the nominal value of loans taken minus

loans extended during this period, while net repayments REP_i is the net nominal value of repayments received by the household on those loans.

The vector of explanatory variables X_i includes village dummy variables, non-land wealth, the age of the household head, an indicator of the length of time the household head's family has been resident in the village, an indicator of the presence of a household member with certain skills, and land holdings. Certain specifications of the model also contain indicators of the educational attainment of the household head.

The village dummy variables capture village-specific effects. There are infrastructural differences across the villages that will influence the net demand for credit. There are also likely to be differences in the social environments of the different villages that affect the availability of information and enforcement mechanisms needed to support these credit transactions. Finally, the village dummy variables capture the effect of the village level production shocks. In the net borrowing equation, the village level shock will affect the price of credit, and therefore net nominal borrowing. In the repayment equation, the village dummy variables control for the mean village production shock in order to isolate the effect of household level deviations from this mean (S_i) on repayments.

The wealth variable is equal to the value of holdings of grain, trading stocks, livestock, and household goods (durable consumer goods such as radios, housewares, and farming implements) at the start of the survey. In figure 1, an increase in wealth (Y_0) rotates the vector C up (this effect will be quite small when T is large). For any C and t, an increase in wealth also rotates the vector I_t up, therefore, the derivative of net repayments with respect to

wealth is always positive. The derivative of net borrowing with respect to wealth is negative. These signs hold for both net borrowers and net lenders.

The age of the household head (AGE) should influence net borrowing and repayments in the same way as other fixed assets. The effect of changes in household fixed assets on loan size and repayments is found from the model with production in the appendix. Intuitively, an increase in fixed asset holdings increases the demand for the working capital needed to utilize the asset. Net borrowing must increase and net repayments to the household must decline as fixed asset holdings increase.¹²

The SKILLS variable is a dummy variable indicating the presence of at least one household member with a special skill. Such skills include carpentry, traditional medicine, tailoring, or being a religious teacher. This variable should act as a fixed asset, increasing the demand for working capital in order to use the skill, and thus increasing the net borrowing of the household and reducing net repayments to the household.

Land ownership is broken down into upland plots (UPLAND) and lowland plots (LOWLAND) because the different types of land require different levels of inputs. Lowlands require much more intensive inputs than do uplands (because the soil is heavier, and because farming can continue year-round). I also include squared terms in land ownership.

The HERELONG variable is a dummy variable which is one if the family of the household head has been in the village for two or more generations (which includes almost 70 percent of the sample). It is possible that families which

¹²As noted above, the age variable poses a special difficulty because of the possibility that its effects might be confused with those of the period variable. The household head's age may be as good a measure of P_1 as is the number of years since the household was formed.

have only recently moved into the village do not have as good access to enforcement mechanisms as do other families. This might reduce net repayments to such households, and might lead them to reduce their net lending (increase their net borrowing).

B. Estimation Results

The results are presented in Tables 4 through 7. Table 4 presents the results of the base specification. In Table 5, separate estimates are presented of the effects on net repayments of shocks to lenders and to borrowers. Tests of the hypothesis that complete risk pooling is achieved through these loan transactions are presented in Tables 6 and 7.

1. State-Contingent Payments.

FIML estimates of the base model are reported in Table 4. The results support the hypothesis that repayments vary according to shocks received. Adverse shocks received by the household lead to increases in repayments to the sample household (reductions in repayments to other households), and the estimated coefficients are significantly different from zero at the one percent level. A one standard deviation shock on upland plots increases repayments to the household by N26; a similar shock on lowlands increases repayments by N31. Recall that the average size of a loan is N291. These results are robust to a variety of different specifications.

Table 5 reports the results of a specification which permits the coefficients of the indices of adverse events on upland and lowland plots to vary according to the sample households net borrower/net lender status. The results show that when adverse shocks are received by sample households which are borrowers, they pay back less. This is consistent with conventional models of loan contracting, as the lower repayments may simply reflect a

higher incidence of default on the part of sample households which receive adverse shocks. On the other hand, the estimates also indicate that when adverse shocks are received by sample households which are net lenders, they are paid back more. This finding cannot be understood in the context of conventional models of the credit market and provides striking evidence that repayments are state-contingent. Owed repayments, therefore, depend upon the realization of random production shocks by both borrower and lender, so these loan transactions permit households (whether borrowing or lending) to insure against at least some portion of output variability. In fact, there is no statistically significant difference between the responses of repayments to adverse shocks received by net lenders and net borrowers.¹³

2. Other Results.

a. Wealth - As expected, increased wealth significantly increases net lending; the effect of wealth on repayments, however, is insignificant. The model was re-estimated with the wealth variable disaggregated into livestock and trading/grain stock components in order to test the joint hypothesis that different types of wealth have different liquidity properties, and that these differences would lead to an effect of asset composition on borrowing behavior. It is not possible, however, to reject the hypothesis that the coefficients of the disaggregated components of wealth are equal.

b. Age - The age of the household head has no significant effect on net borrowing (although the sign is as expected). This result is robust to a variety of different specifications of the AGE variable. Squared terms, dummy

¹³A likelihood ratio test of the restriction that the coefficients of the indices of self-reported adverse shocks are the same for net borrowers and net lenders yields a χ^2 with two degrees of freedom test statistic of 4.58, which is insignificantly different from zero at the 5 percent level.

variables with different age cutoffs, and linear splines in age were all statistically insignificant. On the other hand, older household heads receive significantly higher net repayments. This probably reflects their improved access to information and enforcement mechanisms within the village, and provides a warning that the competitive model misses institutional details that are important to the operation of this market.

c. Period - The period coefficients are insignificantly different from zero in all specifications. This is to be expected if T is large, and is consistent with a Barro-Becker model of inter-generational altruism. The model was re-estimated with the PERIOD variable excluded and the coefficient of the AGE variable free to vary depending upon net borrowing/lending status (Table A.1). In neither equation were the coefficients of the age variable significantly different depending upon net borrowing/lending status. In both equations, the coefficients of the age variable were similar to those in the specification that included the PERIOD variable. This finding supports the hypothesis that the AGE variable is playing the role described in the preceding paragraph, and that T is large enough that households are not making significant yearly adjustments in their net borrowing in anticipation of their final season's transaction.

d. Households containing at least one member with a special skill seem to borrow more than other households, though the coefficient is insignificantly different from zero. This may reflect the extra working capital required to employ these skills. On the other hand, no indicator of formal education - whether Islamic *makaranta* or western primary school - had any effect on net borrowing or repayments. A test of the joint significance

of the education variables yields a $\chi^2(4)$ test statistic of 0.82, which is insignificantly different from zero (see Table A.2).

e. A household whose ancestors have been resident in the village for at least two generations receives significantly higher loan repayments than does a household whose family migrated to the village more recently. As with the AGE variable, this is likely to reflect the better access to information and enforcement mechanisms of better-established households. There is no evidence that newer households respond to this by reducing their net lending.

f. Land - The relationship between net borrowing and land ownership is weak and nonlinear. The estimates imply that net borrowing is nearly insensitive to ownership of upland and lowland land for holdings near the sample mean. The coefficients in the net borrowing equation for the ownership of lowlands are jointly significantly different from zero. The (imprecisely estimated) coefficients imply that net borrowing is an increasing concave function of lowlands ownership. The turning point beyond which net borrowing begins to decline is .5 hectares, just larger than the sample mean. The coefficients in the net borrowing equation for the ownership of uplands are not jointly significantly different from zero. The point estimates imply that net borrowing is a decreasing convex function of uplands ownership; the turning point at which net borrowing begins to increase is 5.2 hectares, which is just larger than the mean holding. There is no statistically significant relationship between ownership of uplands or lowlands and net repayments.

g. Friction - The friction coefficient is significantly different from zero, providing support for the hypothesis of transactions costs.

h. The village dummy variables are among the most significant regressors in each of the specifications. They capture a variety of different

collinear effects. It is impossible to disentangle, for example, the effect of village level production shocks on loan demand from that of differences in infrastructure across villages.

C. Testing Full Risk Pooling.

A Pareto efficient equilibrium with no transactions costs will have the property that risks are completely pooled at the community level. Two tests for full risk pooling are developed in this section. The first test emerges from the result that without transactions costs, the amount borrowed or lent by a household in any period depends only on aggregate community income in that period. That is, net lending is independent of the state of nature after controlling for community income.¹⁴ The second test relies on the fact that if full risk pooling is achieved, the shocks received by the transaction partners of a sample household should have no effect on loan repayments. That is, after controlling for community income, net repayments are independent of the income of transaction partners.

To carry out the first test of full risk pooling, I include measures of the idiosyncratic shocks received in 1987 (before this year's loans were made) in the net borrowing equation. Under the null hypothesis of complete risk pooling, their coefficients are zero. No index of self-reported events on the household farm is available for the 1987 crop season, so the indicator of random production shocks is based on the deviation of the household's per-hectare yield from the village mean yield in 1987. This indicator (SHOCK) is broken down by lowland and upland plots. To control for household fixed

¹⁴This result remains even if some autocorrelation of random shocks is allowed. If village-wide shocks are correlated over time (e.g. droughts may persist) but idiosyncratic shocks are not, then borrowing and lending are unaffected by the idiosyncratic shock.

effects (in reporting, field quality, and skill) the 1987 yield deviation is differenced from the deviation in 1988. If the idiosyncratic shock to output is uncorrelated over time, then this differencing introduces an errors-in-variables problem of the classic sort.

The model is re-estimated with the SHOCK variables included in the loan size equation (Table 6). The hypothesis of complete risk pooling can not be rejected, as the coefficients are not jointly significantly different from zero. The likelihood ratio test of their joint significance yields a $\chi^2(2)$ test statistic of 3.34. However, the coefficient on lowland yields has the expected sign and approaches conventional levels of significance. Exceptionally good yields on lowland farms seem to decrease borrowing in the succeeding season, contrary to the null hypothesis of full risk pooling. The power of the test is difficult to evaluate because of the errors-in-variables that arise when the null hypothesis is rejected. The reported t-ratios of the coefficients of the SHOCK variables and the likelihood ratio test statistic are correct under the null hypothesis.

To carry out the second test of full risk pooling, I include a measure of the adverse shocks received by the transactions partner of the sample household in the repayment equation. This variable is the proportion of the total value of loans of the sample household which was transacted with partners who received an adverse shock between the time the loan was made and when it was repaid. The competitive model developed implies that this variable should have no effect on loan repayments. The effect of the average shock received by the village on repayments should be captured in the village dummy variable. If the shocks received by transactions partners have an effect on repayments received by a sample household, the household has not

sufficiently spread its loan transactions around the village, and has subjected itself to theoretically diversifiable risk. In a Pareto efficient equilibrium, the state-contingent net repayments to the sample household (whether borrowing or lending) will depend on the random shocks it receives and on total village income, but not on the idiosyncratic shocks affecting any other household. The estimate presented in Table 7 indicates that adverse shocks received by transactions partners reduce the loan repayments received by sample households. Loan repayments to sample households and, therefore, consumption by sample households vary according to the realization of idiosyncratic shocks by their transaction partners. While these state-contingent loan transactions allow households to insure against some idiosyncratic risk, they do not permit the realization of a fully Pareto efficient pooling of risk within the village. This is evidence that the competitive model ignores institutional details of the loan transactions which have a real effect on the operation of the credit market.

6. Credit as Insurance: Summary and Directions for Future Research.

The rural credit market in northern Nigeria appears to be significantly different from the idealized markets that appear in theoretical work on the subject and perhaps from its counterparts in other areas of the world. There is only minimal use of collateral and no evidence of contractual interlinkage with other markets. Contractual mechanisms to alleviate the difficulties posed by information asymmetries are not necessary because credit moves through paths that take advantage of the extremely free flow of information within a rural community. In this information environment, state-contingent credit contracts which allow risk sharing between creditor and debtor, and

which conform to the prohibition on fixed interest charges by Shari'a law, are made and enforced.

The existence of such state-contingent payments embedded within loan repayments has been confirmed. In northern Nigeria, the credit market serves its traditional role of smoothing the consumption effects of an income shock over time. In addition, however, this credit market permits households within a community to directly insure each other against idiosyncratic risks.

The estimation carried out in this paper was based on a model of a competitive market for loans in which households are price-takers. This Walrasian approach has enabled me to outline the general equilibrium consequences of state-contingent contracting, and to derive the efficiency properties of such equilibria. The dynamic paths of the terms at which loans are made and of individual households' participation in the credit market became clear. Moreover, the estimation results accord well with the predictions of the general equilibrium model.

The approach taken in this paper treats these highly personalized transactions as abstract events in a perfectly competitive market. However, it is possible to reject the hypothesis that a fully Pareto efficient risk-pooling allocation of village resources is achieved through these loans. Therefore, an investigation of the institutional arrangements which support these loan transactions is required before the economic role of the credit market can be fully understood.

One consequence of the high level of abstraction in this paper is the absence of any attempt to address the social context within which these transactions occur. This absence manifests itself in a number of ways. First, as noted above, the model has given no attention the possibility of

default. More generally, information asymmetries have received only brief attention. While I have argued that information moves between borrowers and lenders more freely than is permitted in much of the theoretical literature, I cannot preclude entirely the possibility of some degree of adverse selection or moral hazard. Most importantly, the approach of this paper sheds no light on the institutional setting of the credit transactions. The loans flow between individuals who live within the same village, or who are relatives, and whose behavior surely is influenced by the norms of this larger community. In Udry (1991a) I attempt to remedy these weaknesses by carefully examining the intricacies of the relationship between a borrower and a lender within the context of rules set by the village community.

An issue immediately arises from the analysis of this paper which can not be directly address by these data. The credit market described above is an important mechanism for pooling risks within a local community. It is known, however, that production shocks tend to be highly correlated over small areas within the semi-arid tropics.¹⁵ What mechanisms exist (if any) to provide for flows of resources into or out of these local communities when they are subject to important community-level shocks? There is evidence from other studies¹⁶ and from the non-survey portions of my fieldwork, that village based long distance traders may play an important role by providing "pipelines" for the flow of resources across community boundaries. This process can be theoretically modelled, but its quantitative importance cannot be evaluated until data is available from a much wider cross section, or from a time series over a particular village.

¹⁵ See Ruthenberg (1971).

¹⁶See especially Clough (1981, 1986).

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Appendix A: A Competitive Model

The first order conditions from equations 1-3 yield:

$$\begin{aligned} \text{A1. } q_1^s(h_0) &= \frac{\beta \pi^s U'(c_1^s(h_0))}{U'(c_0)} \quad \text{for all } s, \\ \text{A2. } q_t^s(h_{t-1}) &= \frac{\beta \pi^s U'(c_t^s(h_{t-1}))}{U'(c_{t-1}^{s_{t-1}}(h_{t-1}))} \quad \text{for all } s, 1 < t \leq T, \end{aligned}$$

where $c_{t-1}^{s_{t-1}}(h_{t-1})$ is consumption in state s_{t-1} realized in period $t-1$ in history h_{t-1} . We can use the result that consumption will be time-and history-independent in any Pareto optimum to find:

$$\text{A3. } \frac{q_t^s(h_{t-1})}{q_1^s} = \frac{U'(c_{t-1}^{s_{t-1}}(h_{t-1}))}{U'(c_0)}, \quad \text{for all } s, 1 \leq t \leq T.$$

Therefore, the scaling factor τ in any period will depend only on realized consumption in the previous period, $c_{t-1}^{s_{t-1}}(h_{t-1})$, which in turn depends only on total community income.

Adding Production.

Let $Y = g(s, k)$, where k is the amount of the good Y devoted to production on a fixed amount of land. Since the amount of land is fixed, it is embodied in the function $g()$. There is no labor; corn is simply invested to produce more corn. The budget constraints must be modified:

$$\begin{aligned} \text{A4. } c_0 &= Y_0 - q_1(h_0) \cdot R_1(h_0) - k_1(h_0) \\ c_t^s(h_{t-1}) &= g(s, k_t) + R_t^s(h_{t-1}) - q_{t+1}(h_t) \cdot R_{t+1}(h_t) - k_{t+1}(h_t) \\ c_T^s(h_{T-1}) &= g(s, k_T) + R_T^s(h_{T-1}). \end{aligned}$$

Using the F.O.C. for securities purchases and k_t , we find:

$$\text{A5. } \tau_t \sum_s \left[q^s \delta g(s, k) / \delta k_t \right] = 1 \quad \text{for } 1 \leq t \leq T.$$

This can be interpreted as $MVP_k = MC$, and the production decision is separable from consumption. If $g(s, k) = \theta^s g(k)$ this simplifies to

$$\text{A6. } \tau_t g'(k_t) \times \sum_s q^s \theta^s = 1$$

and households which own farms whose output is less correlated with overall

output (as indexed by q) invest more.

Adding Alternative Assets.

Y is now $Y(s, k^1, k^2)$, where k^1 and k^2 are analogous to k above. The fixed amounts of land to which k^1 and k^2 are applied are embodied in the function Y .

The budget constraints become:

$$\begin{aligned}
 \text{A7. } c_0 &= Y_0 - q_1(h_0) \cdot R_1(h_0) - k_1^1(h_0) - k_1^2(h_0) \\
 c_t^s(h_{t-1}) &= Y(s, k_t^1, k_t^2) + R_t^s(h_{t-1}) - q_{t+1}(h_t) \cdot R_{t+1}(h_t) - k_{t+1}^1(h_t) \\
 &\quad - k_{t+1}^2(h_t) \\
 c_T^s(h_{T-1}) &= Y(s, k_T^1, k_T^2) + R_T^s(h_{T-1}),
 \end{aligned}$$

where we may wish to specialize $Y(s, k^1, k^2)$ to $g(s, k^1) + h(s, k^2)$. With multiplicative shocks this becomes $\theta^s g(k^1) + \Omega^s h(k^2)$, where $\pi \cdot \theta = \pi \cdot \Omega = 1$. More generally, as long as $\delta^2 Y / \delta k^1 \delta k^2 = 0$ the F.O.C. reported above do not change. The F.O.C. with respect to k_t^2 are analogous to those for k_t , and yield:

$$\text{A8. } r_t \sum_s \left[q^s \frac{\delta h(s, k^2)}{\delta k_t^2} \right] = 1 \quad \text{for } 1 \leq t \leq T.$$

or if we assume multiplicative shocks:

$$\text{A9. } r_t h'(k_t^2) \times \sum_s q^s \cdot \Omega^s = 1.$$

Note in particular that investment in these alternative assets is independent of the correlation between Ω and θ . There is no incentive to diversify at the household level. All diversification remains at the village level.

Appendix B: The Likelihood Function

Consider the contributions to the sample likelihood of three observationally distinguishable groups of households: (1) those who did not participate in the credit market; (2) those who were net borrowers; (3) those who were net lenders.

(1) For household i which did not participate in the market, the model of equations 20-22 implies

$$X_i \alpha + \alpha P_{B i} + \nu_{1i} < 0 \quad \text{and}$$

$$X_i \alpha + \alpha P_{L i} + \nu_{1i} - F > 0.$$

The contribution of this household to the sample likelihood is

$$\Pr(-\alpha P_{B i} > \nu_{1i} + X_i \alpha > -\alpha P_{L i} + F).$$

(2) For household j which was a net borrower, the model implies

$$\nu_{1j} = B_j - X_j \alpha - \alpha P_{B j} = \bar{\nu}_{1j} \quad \text{and}$$

$$\nu_{2j} = \text{REP}_j - X_j \beta - \beta P_{B j} - S_j \gamma = \bar{\nu}_{2j}.$$

The contribution of this household to the sample likelihood is then

$$f(\bar{\nu}_{1j}, \bar{\nu}_{2j}),$$

where $f()$ is the bivariate normal density.

(3) For household k which was a net lender, the model implies

$$\nu_{1k} = B_k - X_k \alpha - \alpha P_{L k} + F = \bar{\nu}_{1k} \quad \text{and}$$

$$\nu_{2k} = \text{REP}_k - X_k \beta - \beta P_{L k} - S_k \gamma = \bar{\nu}_{2k}.$$

The contribution of this household to the sample likelihood is then

$$f(\bar{\nu}_{1k}, \bar{\nu}_{2k}).$$

The sample likelihood is the product of the individual contributions of the 196 observations.

Table 1: Summary Data (n=198)

	Mean	Std. Deviation
Household size	8.5	4.1
--males aged 10-60	2.7	1.7
- household head	1.0	
- all children over 10	1.0	1.4
- other males over 10	.7	1.1
--female aged 10-60	2.0	1.3
- wives	1.7	.9
- children over 10	.3	.7
--young children	3.4	2.4
--elderly	.4	.7
Age of household head	42	12.4
Operational land holdings (Ha)	3.8	4.3
-- uplands	3.3	4.0
-- fadama	.5	1.0
Owned land (Ha)	3.6	5.1
--uplands	3.2	4.7
--fadama	.4	1.0
Value of livestock (July)	N4154	N14922
-excluding 2 Fulani households	N2700	N7884
Value of grain holdings (Naira)		
-- August	597	114
-- January	5058	978
Daily male agricultural wage	N19	N47*
Loan size (Naira) (n=821)	291	719
Household totals, over survey period (Naira):		
-- Gross Borrowing	352	1015
-- Gross Lending	596	2679

The exchange rate ranged from \$1 = N4 in February, 1988 to \$1 = N7 in February, 1989.

*The high variability results from seasonal changes in the wage rate.

Table 2: Realized Terms vs. Borrower and Lender Shocks Received

Adverse shock received by:	<u>Sample means</u>		
	monthly interest rates	simple interest rates	repayment period in days
(A) Borrower			
-no shock	0.5%	20.4%	67
-shock	-4.0%	-0.6%	72
Impact of shock on mean: (t)	lower (1.58)	lower (2.20)	longer (1.03)
(B) Lender			
-no shock	-7.5%	-5.0%	89
-shock	2.6%	11.8%	80
Impact of shock on mean: (t)	higher (4.56)	higher (3.06)	shorter (1.89)

The impact of the shocks is judged by a two-sided t-test of equal means ($\mu_{\text{no shock}} - \mu_{\text{shock}}$). The absolute value of the t-statistic is in parentheses.

The definition of 'adverse shock' is that of table 4, broadened to include lenders:

1. A respondent (borrower or lender) is judged to have received an adverse shock if he reported an unexpected adverse event on any of the fields he farms during the term of the loan. Common events were flooding, wind damage, or infestation by insects.

2. The other party (borrower or lender) is judged to have received an adverse shock if the respondent reported an unexpected, serious event that occurred in the other household during the term of the loan. Common events were farming events as in (1), and medical problems, rain damage to houses, and other 'household emergencies'.

Table 3: Variables Used in the Competitive Model

		<u>Mean</u>	<u>Std.</u>
LOAN SIZE :	net amount borrowed (x N100)	-1.91	24.16
REPAYMENT :	net amount repaid (xN100) (to sample household by others)	2.50	26.75
WEALTH :	value of livestock, household articles, grain and trading stocks evaluated at the start of the survey (x1000).	2.25	45.12
AGE :	age in years of household head.	40.64	12.23
PRIMARY :	number of years of western schooling completed by household head.	0.54	1.73
ISLAM :	number of Koran sections known by household head.	23.69	24.26
HERELONG :	dummy variable. 1 if family of household head has been in village 2 or more generations.	0.68	0.47
SKILLS :	dummy variable. 1 if at least one member of household has special skills.	0.60	0.24
UPLAND :	gona (upland) land owned in hectares.	3.24	4.69
LOWLAND :	fadama (lowland) land owned in hectares.	0.44	1.04
PERIOD:	number of years since the household head first married, or since he moved to this village, whichever is smaller.	16.07	10.00
UPROBLEM :	index of self-reported problems on upland farms.	0.22	0.35
LPROBLEM :	index of self-reported problems on lowland farms.	0.27	0.26
USHOCK :	difference between yield last year and this year on uplands.	0.49	1.20
LSHOCK :	difference between yield last year and this year on lowlands.	0.54	0.83
PARTPROB :	proportion of loans with partners who received adverse shocks	0.20	0.30

TABLE 4
Competitive Model FIML Estimates

Variable	Loan Size (net amount borrowed) (xN100)		Repayments (net amount paid in) (xN100)	
	Parameter	T-Ratio	Parameter	T-Ratio
CONSTANT	-2.947	-2.40	-0.989	-2.02
VILLAGE1	1.490	1.88	-0.287	-0.92
VILLAGE2	2.081	2.94	0.016	0.05
VILLAGE3	0.529	0.72	-0.601	-2.04
WEALTH	-0.058	-1.83	-0.010	-0.54
AGE	0.029	0.96	0.017	1.40
HERELONG	0.227	0.38	0.511	2.14
SKILLS DUMMY	0.456	0.85	-0.317	-1.48
UPLAND	-0.291	-1.73*	0.001	0.02 [¶]
UPLAND SQUARED	0.028	3.00*	0.000	0.01 [¶]
LOWLAND	0.259	0.31 [#]	-0.347	-1.10 [§]
LOWLAND SQUARED	-0.258	-1.32 [#]	0.073	0.99 [§]
PERIOD				
LENDING	-0.002	-0.06	-0.009	-0.56
BORROWING	-0.025	-0.64	-0.008	-0.44
FRICTION CUTOFF	-1.869	-3.38		
INDEX OF SELF-REPORTED SHOCKS				
ON UPLANDS			0.742	2.08
ON LOWLANDS			1.200	3.07
σ	1.829	30.55	1.882	28.27
CORRELATION COEFFICIENT	-0.948	-24.76		

$$-\text{LN(Likelihood)} = 848.86$$

*Not jointly significant. The likelihood ratio test of the restriction that both uplands coefficients are zero yields a $\chi^2(2)$ test statistic of 0.18.

[#]Jointly significant at the 5 percent level. The likelihood ratio test of the restriction that both lowlands coefficients are zero yields a $\chi^2(2)$ test statistic of 6.43.

[¶]Not jointly significant. The likelihood ratio test of the restriction that both uplands coefficients are zero yields a $\chi^2(2)$ test statistic of 2.47.

[§]Not jointly significant. The likelihood ratio test of the restriction that both lowlands coefficients are zero yields a $\chi^2(2)$ test statistic of 1.21.

TABLE 5
Testing the Responsiveness of Contract Terms to Shocks:
Net Borrowing Households vs. Net Lending Households

Variable	Loan Size (net amount borrowed) (xN100)		Repayments (net amount paid in) (xN100)	
	Parameter	T-Ratio	Parameter	T-Ratio
CONSTANT	-2.947	-2.40	-1.038	-2.12
VILLAGE1	1.490	1.88	-0.209	-0.67
VILLAGE2	2.081	2.94	-0.001	-0.00
VILLAGE3	0.529	0.72	-0.520	-1.78
WEALTH	-0.058	-1.83	-0.008	-0.44
AGE	0.029	0.96	0.021	1.72
HERELONG	0.227	0.38	0.472	1.98
SKILLS DUMMY	0.456	0.85	-0.320	-1.51
UPLAND	-0.291	-1.73*	0.008	0.13 [¶]
UPLAND SQUARED	0.028	3.00*	-0.000	-0.04 [¶]
LOWLAND	0.259	0.31 [#]	-0.429	-1.37 [§]
LOWLAND SQUARED	-0.258	-1.32 [#]	0.090	1.23 [§]
PERIOD				
LENDING	-0.002	-0.06	-0.008	-0.48
BORROWING	-0.025	-0.64	-0.020	-1.08
FRICITION CUTOFF	-1.869	-3.38		
INDEX OF SELF-REPORTED SHOCKS				
FOR NET BORROWERS				
ON UPLANDS			0.338	0.70
ON LOWLANDS			1.941	3.78
FOR NET LENDERS				
ON UPLANDS			0.969	2.14
ON LOWLANDS			0.350	0.63
σ	1.829	30.55	1.876	28.30
CORRELATION COEFFICIENT	-0.950	-24.97		

-LN(Likelihood) = 846.57

*Not jointly significant. The likelihood ratio test of the restriction that both uplands coefficients are zero yields a $\chi^2(2)$ test statistic of 0.06.

[#]Jointly significant at the 5 percent level. The likelihood ratio test of the restriction that both lowlands coefficients are zero yields a $\chi^2(2)$ test statistic of 6.43.

[¶]Not jointly significant. The likelihood ratio test of the restriction that both uplands coefficients are zero yields a $\chi^2(2)$ test statistic of 0.04.

[§]Not jointly significant. The likelihood ratio test of the restriction that both lowlands coefficients are zero yields a $\chi^2(2)$ test statistic of 1.89.

TABLE 6
Testing Full Risk Pooling—Last Year's Yields

Variable	Loan Size (net amount borrowed) (xN100)		Repayments (net amount paid in) (xN100)	
	Parameter	T-Ratio	Parameter	T-Ratio
CONSTANT	-2.725	-2.09	-0.988	-2.03
VILLAGE1	1.068	1.31	-0.292	-0.95
VILLAGE2	1.856	2.38	0.014	0.05
VILLAGE3	0.750	0.99	-0.599	-2.05
WEALTH	-0.055	-1.66	-0.010	-0.53
AGE	0.016	0.52	0.017	1.41
HERELONG	-0.098	-0.16	0.510	2.15
SKILLS DUMMY	0.645	1.16	-0.316	-1.48
UPLAND	0.113	0.76*	0.004	0.08 [¶]
UPLAND SQUARED	-0.002	-0.50*	-0.000	-0.08 [¶]
LOWLAND	0.431	0.50 [#]	-0.343	-1.10 [§]
LOWLAND SQUARED	-0.237	-1.15 [#]	0.073	0.99 [§]
PERIOD				
LENDING	-0.006	-0.15	-0.009	-0.56
BORROWING	-0.020	-0.51	-0.008	-0.44
FRICITION CUTOFF	-2.001	-3.51		
INDEX OF SELF-REPORTED SHOCKS				
ON UPLANDS			0.743	2.09
ON LOWLANDS			1.199	3.08
YIELD LAST YEAR				
ON UPLANDS	0.030	0.13		
ON LOWLANDS	-0.489	-1.49		
σ	1.859	30.63	1.909	28.22
CORRELATION COEFFICIENT	-0.952	-25.38		

-LN(Likelihood) = 847.19

*Not jointly significant. The likelihood ratio test of the restriction that both uplands coefficients are zero yields a $\chi^2(2)$ test statistic of 0.71.

[#]Not jointly significant. The likelihood ratio test of the restriction that both lowlands coefficients are zero yields a $\chi^2(2)$ test statistic of 3.30.

[¶]Not jointly significant. The likelihood ratio test of the restriction that both uplands coefficients are zero yields a $\chi^2(2)$ test statistic of 0.01.

[§]Not jointly significant. The likelihood ratio test of the restriction that both lowlands coefficients are zero yields a $\chi^2(2)$ test statistic of 1.23.

TABLE 7
Testing Full Risk Pooling—The Significance of Partner's Shocks

Variable	Loan Size (net amount borrowed) (xN100)		Repayments (net amount paid in) (xN100)	
	Parameter	T-Ratio	Parameter	T-Ratio
CONSTANT	-3.095	-2.42	-0.756	-1.54
VILLAGE1	1.091	1.33	-0.258	-0.86
VILLAGE2	1.951	2.65	0.123	0.44
VILLAGE3	0.798	1.05	-0.564	-1.96
WEALTH	-0.055	-1.65	-0.010	-0.57
AGE	0.020	0.64	0.016	1.37
HERELONG	0.009	0.01	0.466	1.98
SKILLS DUMMY	0.713	1.28	-0.330	-1.58
UPLAND	0.086	0.59*	0.005	0.09 [¶]
UPLAND SQUARED	-0.002	-0.36*	-0.000	-0.15 [¶]
LOWLAND	0.650	0.77 [#]	-0.377	-1.23 [§]
LOWLAND SQUARED	-0.288	-1.41 [#]	0.079	1.09 [§]
PERIOD				
LENDING	-0.012	-0.31	-0.007	-0.43
BORROWING	-0.026	-0.64	-0.010	-0.56
FRICITION CUTOFF	-2.032	-3.54		
INDEX OF SELF-REPORTED SHOCKS				
ON UPLANDS			0.771	2.21
ON LOWLANDS			1.051	2.70
LOAN PARTNERS WITH SHOCKS (proportion of total loan value)			-0.648	-2.10
σ	1.867	30.62	1.909	28.20
CORRELATION COEFFICIENT	-0.953	-25.67		

$$-\ln(\text{Likelihood}) = 846.15$$

*Not jointly significant. The likelihood ratio test of the restriction that both uplands coefficients are zero yields a $\chi^2(2)$ test statistic of 0.45.

[¶]Not jointly significant. The likelihood ratio test of the restriction that both lowlands coefficients are zero yields a $\chi^2(2)$ test statistic of 3.70.

[¶]Not jointly significant. The likelihood ratio test of the restriction that both uplands coefficients are zero yields a $\chi^2(2)$ test statistic of 0.03.

[§]Not jointly significant. The likelihood ratio test of the restriction that both lowlands coefficients are zero yields a $\chi^2(2)$ test statistic of 1.53.

TABLE A.1
Interaction Effects Between Age and Net
Borrowing/Lending Status

Variable	Loan Size (net amount borrowed) (xN100)		Repayments (net amount paid in) (xN100)	
	Parameter	T-Ratio	Parameter	T-Ratio
CONSTANT	-2.836	-2.24	-1.140	-2.56
VILLAGE1	1.168	1.39	-0.186	-0.59
VILLAGE2	1.982	2.67	0.032	0.11
VILLAGE3	0.681	0.90	-0.573	-2.00
WEALTH	-0.055	-1.65	-0.005	-0.27
HERELONG	-0.058	-0.09	0.497	2.10
SKILLS DUMMY	0.098	0.34	-0.194	-1.79
UPLAND	0.087	0.59*	0.015	0.29 [¶]
UPLAND SQUARED	-0.002	-0.34*	-0.000	-0.29 [¶]
LOWLAND	0.661	0.78 [#]	-0.384	-1.25 [§]
LOWLAND SQUARED	-0.291	-1.43 [#]	0.080	1.10 [§]
AGE				
LENDING	0.005	0.21	0.013	1.36
BORROWING	0.012	0.46	0.018	1.88
FRICITION CUTOFF	-2.561	-2.43		
INDEX OF SELF-REPORTED SHOCKS				
ON UPLANDS			0.729	2.15
ON LOWLANDS			1.281	3.33
σ	1.871	30.63	1.937	28.07
CORRELATION COEFFICIENT	-0.955	-25.94		

-LN(Likelihood) = 848.45

*Not jointly significant. The likelihood ratio test of the restriction that both uplands coefficients are zero yields a $\chi^2(2)$ test statistic of 0.49.

[#]Not jointly significant. The likelihood ratio test of the restriction that both lowlands coefficients are zero yields a $\chi^2(2)$ test statistic of 3.71.

[¶]Not jointly significant. The likelihood ratio test of the restriction that both uplands coefficients are zero yields a $\chi^2(2)$ test statistic of 0.09.

[§]Not jointly significant. The likelihood ratio test of the restriction that both lowlands coefficients are zero yields a $\chi^2(2)$ test statistic of 1.59.

TABLE A.2
Testing the Effect of Education

Variable	Loan Size (net amount borrowed) (xN100)		Repayments (net amount paid in) (xN100)	
	Parameter	T-Ratio	Parameter	T-Ratio
CONSTANT	-2.550	-2.00	-1.060	-2.25
VILLAGE1	1.161	1.38	-0.160	-0.50
VILLAGE2	2.036	2.74	0.033	0.12
VILLAGE3	0.741	0.97	-0.533	-1.84
WEALTH	-0.056	-1.67	-0.006	-0.31
AGE	0.018	0.56	0.020	1.60
HERELONG	-0.044	-0.07	0.475	2.00
SKILLS DUMMY	0.131	0.45	-0.206	-1.86
UPLAND	0.078	0.53*	0.017	0.32 [¶]
UPLAND SQUARED	-0.001	-0.29*	-0.000	-0.34 [¶]
LOWLAND	0.741	0.87 [#]	-0.370	-1.19 [§]
LOWLAND SQUARED	-0.301	-1.47 [#]	0.079	1.08 [§]
PRIMARY	-0.126	-0.77	-0.044	-0.71
ISLAM	0.001	0.12	-0.002	-0.49
PERIOD				
LENDING	-0.018	-0.44	-0.008	-0.48
BORROWING	-0.032	-0.76	-0.011	-0.61
FRICITION CUTOFF	-2.021	-3.53		
INDEX OF SELF-REPORTED SHOCKS				
ON UPLANDS			0.669	1.87
ON LOWLANDS			1.299	3.32
σ	1.869	30.60	1.913	28.05
CORRELATION COEFFICIENT	-0.953	-25.50		

-LN(Likelihood) = 847.73

*Not jointly significant. The likelihood ratio test of the restriction that both uplands coefficients are zero yields a $\chi^2(2)$ test statistic of 0.41.

[#]Not jointly significant. The likelihood ratio test of the restriction that both lowlands coefficients are zero yields a $\chi^2(2)$ test statistic of 3.59.

[¶]Not jointly significant. The likelihood ratio test of the restriction that both uplands coefficients are zero yields a $\chi^2(2)$ test statistic of 0.12.

[§]Not jointly significant. The likelihood ratio test of the restriction that both lowlands coefficients are zero yields a $\chi^2(2)$ test statistic of 1.43.

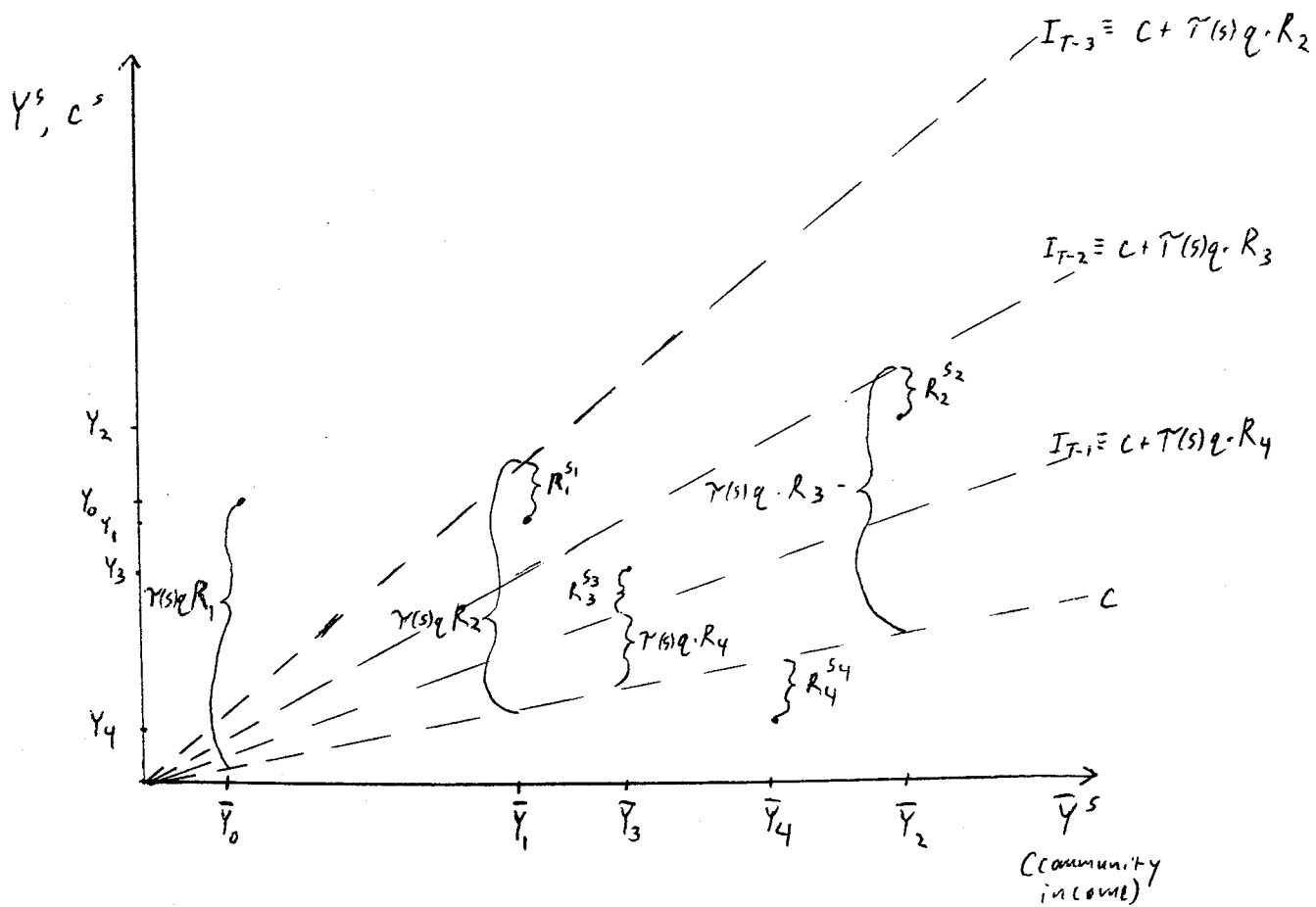


Figure 1

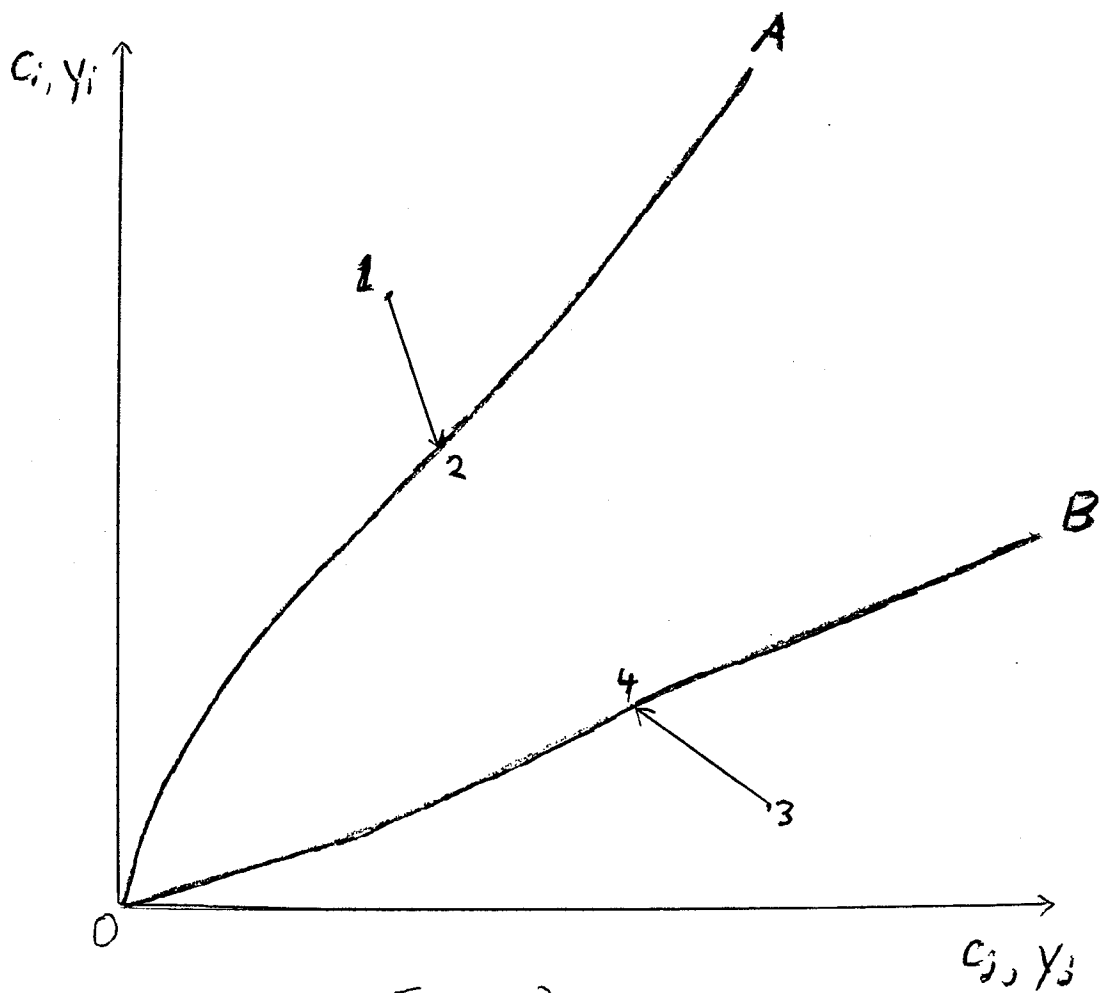


Figure 2