ABSTRACT

Title of Dissertation: THE ECONOMICS OF AGRICULTURAL LABOR EXCHANGE WITH EVIDENCE FROM INDONESIA

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In agricultural labor exchange, farmers temporarily pool their labor into teams and complete a task on each team member's plot in succession. Labor time is exchanged between team members under strict reciprocity and without pay. The use of agricultural labor exchange in developing countries is widespread, but has received little attention from economists. This dissertation investigates the motivation for the formation of labor exchange teams by considering the individual farmer's decision to participate. The analysis focuses on the two most prominent motivations for labor exchange: credit and labor market imperfections and the technological benefits of teamwork. A theoretical model of demand for labor exchange under factor market imperfections generalizes existing models of the organization of agricultural production by allowing for returns to teamwork and labor exchange. This generalization accounts for empirically relevant modes of production that were previously ruled out. The model establishes positive marginal returns to teamwork as a necessary condition for labor exchange when non-household labor exhibits moral hazard. The empirical analysis tests the implications of the model using primary data on agricultural households from Indonesia. Production function estimates demonstrate positive returns to teamwork for a sample of rice and corn farmers, establishing the necessary condition for labor exchange. Estimates of the farmer's decision to participate in labor exchange subject to unobserved working capital constraints are estimated for alternative constraint status assignment rules and via the EM algorithm. Results show that the effect of working capital holdings on the probability of participating in labor exchange has the inverted-U shape predicted by the model for working capital constrained households. Also, labor exchange use is responsive to wages in the paid labor market, and is constrained by the local distribution of land and crop choice. These findings imply that labor exchange operates in conjunction with paid labor markets; that labor exchange is a source of productivity growth for poor capital constrained farmers; and that the institution of labor exchange is likely to persist much later into the process of development than suggested by previous studies.

THE ECONOMICS OF AGRICULTURAL LABOR EXCHANGE
WITH EVIDENCE FROM INDONESIA

by

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1 Introduction

1.1 Overview

A common agricultural labor arrangement in many developing countries is *labor exchange* or *work sharing*. Under a typical form of labor exchange, farmers temporarily pool their labor into teams and complete a task such as planting, weeding or harvesting a crop on each team member's plot in succession. Labor time is exchanged between team members under strict reciprocity and without pay, with the possible exception of a mid-day meal. Under this type of labor exchange, the entire exchange is completed in a matter of days or weeks. In another variant of exchange labor, the terms of the reciprocation are not clearly specified at the outset, so that the eventual completion of the exchange can be for different activities and over a longer period.

Researchers disagree about the origin and age of labor exchange as an agrarian institution.[1] This disagreement has arisen in part because the use of labor exchange is often overlooked, even where it is widespread. Nonetheless, there is considerable evidence of labor exchange teams operating in many parts of the developing world, currently and throughout the twentieth century.[2] Although labor exchange typically

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[1] Swindell (1985) speculates that labor exchange is a relatively recent phenomenon that must have developed in Africa, for example, only after the decline in slavery there at the end of the nineteenth century. However, Homans (1960) and Kuznesof (1980) provide evidence of the latter type of labor exchange in thirteenth century England and eighteenth century Brazil, respectively.

[2] For evidence on the use of labor exchange, see Geschiere (1995) on Cameroon; Fafchamps (1993) on Burkina Faso; Swindell on the Gambia (1985); Stone (1996) on Nigeria; Worby (1995) on Zimbabwe; Barnard (1970) on Malaysia; Ganjanapan (1989) on Thailand; Fegan (1989) on the Philippines; Geertz (1965), Hart (1980) and Naylor (1991) on Indonesia; Guillet (1980), Chibnik and de Jong (1989), and Jacoby (1992) on Peru. Erasmus (1956) provides first-hand evidence of labor exchange in Haiti, Colombia,

constitutes a small share of total labor supply for a given crop, it can account for a considerable fraction of labor traded for certain activities. Moreover, modern labor exchange teams are often found operating in areas with active labor markets.

In the sociological literature that has dominated research on labor exchange, factor market failures are the most prominent economic motivation for labor exchange, in part because exchange labor has been common as a pre-market form of trade in underdeveloped rural areas (see, for example, Moore, 1975; Guillet, 1980; and Geschiere, 1995). When labor markets are thin or cash holdings are limited, labor exchange provides a mechanism for circumventing markets and gathering a team of laborers without the commitment of cash or food stores. This argument is consistent with the principles of transaction cost economics (Coase, 1937; Williamson 1979, 1986) wherein the institution of labor exchange arises because transaction costs in labor or credit markets make reliance on the paid labor market prohibitively expensive for the task at hand. Under this hypothesis, we should expect greater reliance on labor exchange during peak periods of labor demand, in areas with few agricultural laborers, or in regions where farming is not highly commercialized.

Another significant economic motivation for labor exchange is as a source of team labor for tasks that exhibit returns to teamwork (Moore, 1975; Goethals, 1967; and Wong, 1971). The team component to exchange labor allows tasks to be coordinated by several

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Ecuador, Peru and Chile. He cites other evidence, mostly for the early twentieth century, from many other countries, including China, Guatemala, Mexico, South Africa, and Sudan. In personal correspondence, Markus Goldstein confirmed the presence of labor exchange in Southern Ghana for a sample of farm households in 1997-98. For an introduction to the sample, see Goldstein (2000). Kimball (1949) provides workers and enables faster completion of time-sensitive tasks, such as transplanting rice seedlings. Other possible motivations that have received some attention include improvements in work quality (Worby, 1995; Stone, 1996), presumably due to less costly monitoring or improved incentives (Moore, 1975); access to tools or bullocks owned by teammates in interlinked exchanges; and psychological or motivational benefits from working with others (Moore, 1975; Goethals, 1967).

Casual observation of agricultural households in Indonesia provides some evidence for these competing motivations for labor exchange. In a sample of 1494 households on which this research is based, labor exchange was common in the more remote regions of South Sulawesi and West Nusa Tenggara, where average cultivated area was 1.7 and 1.9 hectares, respectively, and few household heads are employed regularly as agricultural laborers. However, labor exchange is also prominent in the densely populated areas of rural Central Java. There, farm sizes average only 0.65 hectares and labor markets are active and have shown no imperfections (see Benjamin, 1992; Hart, 1986). Among all farmers in the data, the use of labor exchange is most common for planting (43%) and harvesting (24%) activities. These activities exhibit the greatest returns to teamwork. However, they also represent the periods of greatest demand for agricultural labor, when search costs in the labor market are high.

The prevalence of labor exchange is also determined by its structure. Most importantly, team members are required to have control rights over a plot of land. They also must

evidence of exchange labor teams among Michigan farmers in the 1940s, and Gröger (1981) describes their persistence in Aveyron, France.

match on-farm exchange labor demand with household labor supplied off-farm to other team members. In labor exchange teams requiring immediate reciprocity, members must have considerable homogeneity in crops grown, plot size and quality, timing of tasks, and use of mechanization. This suggests that the adoption of exchange labor may be highly dependent on the nature of local production technology and the distribution of land and other endowments.

These economic motivations and constraints for labor exchange are not well integrated in existing literature, and their relative importance has never been tested. In addition, the role of the economics of incentives in rural organization has been mostly ignored. If household members as residual claimants have the strongest incentives to supply effort, then the reduction in the share of household labor in total on-farm labor demand that accompanies labor exchange can only be justified by some positive returns to teamwork. These effects have important implications for who joins labor exchange teams and for the tasks to which exchange labor is applied.

Since Erasmus (1956, 1961), many have predicted that the prevalence of labor exchange will decline during the process of economic development, as markets develop and agriculture becomes more commercialized. However, Guillet (1980), Chibnik and de Jong (1989), and Stone (1996) emphasize its persistence and argue that predictions of the demise of labor exchange are mostly unrealized.[3] These arguments hinge on the importance of factor market failures as a determinant of labor exchange and on the interplay of labor and credit markets during the process of development. Although the growth of cash cropping and increased access to credit are likely to reduce exchange labor demand, the role of the labor market is unclear. If increased commercialization of agriculture increases demand for labor, it could stimulate development of rural labor markets and reduce demand for exchange labor. However, in their classic models of economic development, Lewis (1954) and Ranis and Fei (1961) characterize the process of development by a surplus labor force moving out of agriculture into industrial production. This process would be accompanied by increasing demand for exchange labor as the pool of paid workers for hire in the labor market shrinks.

Agricultural labor exchange also has implications for theories of population growth and agricultural change. Boserup (1965) describes how, in communities with low population density and extensive agricultural systems, population growth leads to agricultural intensification with shorter fallow periods and higher labor-to-land ratios. In this setting, labor exchange can assist farmers in adjusting to intensification by reducing the time spent at a given task on each plot and by harnessing productivity gains from teamwork.[4] By suppressing demand for a large household labor force, the availability of labor exchange could also reduce fertility in this setting. This would indirectly slow the process of agricultural intensification.

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[3] There is evidence of a resurgence of labor exchange in response to increased commercialization of farm output in Peru (Chibnik and de Jong (1989)) and following agricultural intensification in Zimbabwe (Worby (1995)).

[4] Stone (1996) argues that this was the role of exchange labor used by the Kofyar in Nigeria.

As a mature and significant non-market institution for reciprocal labor exchange, agricultural labor exchange teams can provide insights into the performance of labor exchange in other settings and of exchange relationships in general. Many of the defining characteristics of agricultural labor exchange teams, including the reciprocal swap of labor time (either immediately or delayed), joint production by team members, the absence of monetary payments, and the rotating accrual of benefits from pooling factors rather than output across economic units are found to varying degrees in many other settings. Barn raisings, for example, which are still conducted by the Amish peoples in the United States, are organized very similarly to agricultural labor exchange teams. They involve the reciprocal exchange of unpaid labor over time for team production in identical activities, where the output from one production cycle is privately owned. Childcare swaps, in which parents trade time caring for each other's children also involve the unpaid exchange of labor time in the production of private goods (in this case, children), but the production is not through teams. This makes it possible that the time exchanged is not reciprocal on a one-to-one basis. In some more organized childcare swaps, parents caring for others' children earn chits that can be called in for labor services provided by another parent. In this case, the absence of team production makes it possible for the labor exchange to become monetized. The organization of work teams in many advertising agencies and law firms also exhibit aspects of reciprocal labor exchange. In a typical large law firm, for example, a team of attorneys serves each client.[5] The positions of lead attorney, second chair, etc., on a case are usually assigned by a partner in the firm based on seniority, importance of the case, and past performance.

[5] I would like to thank Anthony O'Donnell, J.D., for a very useful discussion about the organization of labor in large law firms in the United States.

These positions are sometimes rotated from case to case, so that the lead attorney on a case may serve under his second chair on another case. Although all attorneys are compensated for their time, the lead attorney typically earns more non-pecuniary (e.g., reputation) benefits within the firm from favorable team performance.[6] That is, the lead attorney enjoys the greatest private rewards from joint production. Moreover, each team member's noncontractable effort contribution is a function of how the lead attorney is expected to perform when the roles are reversed. Although this form of teamwork tends to derive more from specialization and to be more hierarchical than agricultural labor exchange, the non-pecuniary rewards in this system of rotating, reciprocal exchange closely mirror the rotating rewards of agricultural labor exchange.[7]

More generally, exchange relationships between agents with heterogeneous resource endowments raise a number of significant economic issues concerning exchange relationship formation and duration, factor allocation and welfare distribution. These issues have been studied to a limited extent for some forms of reciprocal exchange relationships, such as rotating savings and credit associations (see Besley et al, 1993, 1994). The role of reciprocity in exchange relationships has also begun to receive more attention. Kranton (1996) develops a model explaining the persistence of reciprocal exchange relationships despite the presence of money-based markets. In this model,

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[6] The lead attorney on a successful case may also receive more pecuniary benefits than other team members in the form of larger bonuses and faster promotions. As long as a larger share of the benefits from team production accrue privately to the lead attorney, these arrangements have the central characteristics of reciprocal labor exchange. This interpretation of these non-salary gains to the lead attorney is incorrect only if all of the benefits accruing to him can be attributed to his effort and managerial ability, which is unlikely in team production.

[7] See Leibowitz and Tollison (1980) and Blair and Stout (1999) for general descriptions of team production in legal partnerships. These studies focus on the role of the organization of teams in determining incentives to work.

personalized reciprocal exchange can persist for goods that are close substitutes if thin spot markets lead to high search costs for market exchanges. As spot markets develop, these search costs decline, making reciprocity in exchange relationships more difficult to enforce. In the agricultural labor setting, Kranton's analysis implies that high labor market transaction costs can contribute to the persistence of agricultural labor exchange, but that the popularity of personalized labor exchanges may also inhibit the formation of a spot market for labor. Agricultural labor exchange teams provide an excellent context in which to investigate the determinants of reciprocal exchanges because the structural attributes of agricultural labor exchanges have been shown to be robust: they have persisted in the face of market development and have been repeated in disparate areas in developing countries.

The remainder of this chapter describes the operation of labor exchange teams in greater detail, summarizes the literature on the motivation for the use of labor exchange, and introduces the purpose and contribution of this research.

1.2 The Operation of Labor Exchange Teams

> Every participant in a *basiru* (labor exchange) task both knows that his contribution will be exactly matched in kind by the eventual return and can determine from knowledge of the group's size what expenditure and what benefits he will incur through participation. (p. 44)
>
> --Goethals, 1967

Most labor exchange teams in agriculture can be classified into one of the two categories mentioned above, which Erasmus (1956) labeled "exchange labor" and "festive labor".[8] The two can be distinguished primarily by the degree of reciprocity involved and by the size and quality of the meals and other in-kind payments provided.[9] In exchange labor, a team member is obligated to supply as much labor time on the farm of each teammate as he receives from that teammate. Although the work is performed as a team, the reciprocity is individual-specific, so that the exchange of labor time between each pair of team members represents the two sides of a single labor transaction. Typically, a farmer who cannot meet his labor obligation to a teammate can send a family member in his place.[10] Otherwise, he must compensate the teammate whose labor he did not reciprocate either in-kind or with cash at the prevailing wage rate (Goethals, 1967). In a completed

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[8] Erasmus (1956) and Moore (1975) provide comprehensive overviews of the prevalence and design of labor exchange teams and detailed discussions on the motivation for their use. This section on the design and operation of the teams relies on their accounts.

[9] A third form of cooperative labor involves labor pooling for public good provision such as construction of public buildings or roads, or farming communal plots. The reciprocity inherent in these arrangements is relatively diffuse and is oriented toward public good provision. This motivation makes these arrangements distinct from the private exchanges considered here, so they will not be addressed. The latter setting is similar to an agricultural cooperative with output pooling, which has been studied extensively elsewhere.

[10] Goethals (1967) notes that, for a village in West Sumbawa, Indonesia, the substitute worker must have comparable productivity for the task. For example, a man who cannot complete his harvest labor exchange obligation could be replaced by his wife, but she would not be considered an adequate substitute if the work were swidden clearing.

labor exchange transaction, no payments are made between team members. The only exception is that the host member may serve food, particularly if the work is performed over a full day or if the field is remote.[11] Alternatively, team members may agree to bring their own mid-day meal or to break for members to return home to eat. If a meal is provided, it is typically average, although it may include a small premium in quality or quantity. In any case, its value would be a fraction of the daily wage. The convention on supplying meals is agreed to in advance, so that the exchange of equivalent meals is reciprocal too.

In a festive labor arrangement, the host assembles a large team for the work and supplies a large meal, often in a festive atmosphere, when the work is complete. In some cases music and drinking begin while the work ongoing, and team members are regarded as both workers and party guests. There is at most a weak implicit obligation for the host to reciprocate labor to team members in the future. Therefore, the meal and festivities alone constitute payment for the work. This claim is supported by the fact that the invitation to join a festive labor team is often open. The absence of reciprocity and the large in-kind payments suggest that festive labor teams operate more like wage labor than reciprocal labor exchange. They are more common where wage labor markets are thin and decline more rapidly than exchange labor as labor markets develop (Swindell, 1980). Because the focus of this research is reciprocal non-market exchange labor arrangements, festive labor arrangements are not studied in detail here.

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[11] The "host" member or farmer is the one on whose plot the work is currently being performed. In exchange labor teams, this position is rotated in the course of the exchange so that each team member

Many other characteristics of exchange labor teams are conditioned by the reciprocity and by the technology and nature of farm work. For example, reciprocal exchange requires that all team members must have control rights over land. Although it is possible for the activities performed to differ across farms, the seasonality of farming and homogeneity of agroclimatic conditions in an area covered by a labor exchange team suggest that both activities and crops grown are likely to be the same for all team members (Erasmus, 1956). There is evidence of labor exchange being used for all agricultural activities, including land clearing, plowing, planting, weeding, harvesting, threshing and transporting crops (eg, Goethals, 1967).[12] However, various sources cited in Erasmus (1956) indicate that it is most commonly used in agriculture for planting and harvesting crops. Due to costs associated with organizing team activities and traveling between plots, exchange labor teams tend to be small, typically with less than ten members. Team size is also affected by plot size and the activity. For the Indonesian sample used in this research, average team size, where reported, ranged by province from 4.5 farmers in East Java to 10.3 in less-densely populated South Sulawesi. It is common for teams to be formed so that the task on each plot can be completed in one day or half day. Some labor exchanges are organized around the use of farm equipment such as a plow owned by one of the team members (Goethals, 1967). In other cases, the machinery itself is co-owned by several farmers, which facilitates labor exchanges to use the machinery (Kimball, 1949; Gröger, 1981). This interlinkage of labor and equipment changes the requirements for labor reciprocity when only one person owns the equipment, reducing his labor obligation to other team members.

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serves as host once.

The order of rotation of hosting a labor exchange team is determined either by random draw or by seniority of membership (Weil, 1973), with exceptions made for a team member with a compelling reason for hosting at a particular time. If there are benefits to the timing of the activity within the season (eg, it is better to plant as close to the beginning of the rainy season as possible), then the outcome of the hosting rotation can have consequences for the distribution of the team labor productivity among team members.

An important determinant of the membership of a labor exchange team is proximity of fields, in order to limit the time cost of travel between fields (Stone, 1996; Hudson and Hudson, 1967). Subject to this restriction, the composition of a labor exchange team may be based in part on friendship or family ties (Hudson and Hudson, 1967; Weil, 1973). A number of sociologists have noted that labor exchange teammates exhibit considerable homogeneity in social status and ethnicity, and possibly age and gender as well (see Erasmus, 1956; Jay, 1969; Stone, 1996). A common argument for this observation is that it is easier to enforce reciprocity norms among team members of identical socio-economic status or ethnicity because their shared experiences contribute to common values and norms of behavior and because they are more likely to participate together in other transactions that build trust and reinforce these norms. An argument for homogeneity of age and gender composition that receives less attention is that people of similar age and the same gender are more likely to have comparable labor productivity.

[12] In some areas, labor exchange teams are also common for some non-agricultural activities, including house construction.

These regularities in labor exchange team membership may have developed as partial solutions to problems of adverse selection based on farmer ability. Weil (1973) observes an alternative age composition of labor exchange teams in the Gambia, where each team includes one experienced elderly woman, several stronger prime-age adult women, and a few young, inexperienced women. This mode of organization capitalizes on specialization between knowledge and physical strength, and pools labor endowments in part to teach the young. This alternative age composition appears to be less common than age homogeneity.

Possible motivations for labor exchange teams and their characteristics offered in the sociological literature are reviewed in the following section. These motivations are tested empirically in Chapter 4 using the Indonesian data.

1.3 Literature Synthesis on the Economic Motivation for Labor Exchange

> It does seem that cooperative labor is, ceteris paribus, relatively common in areas where there is very little cash cropping, where farmers' incomes are relatively low, and where there is no substantial landless labor force.
>
> --Moore, 1975

In remote, underdeveloped rural areas characterized by subsistence farming, many of the important determinants of agricultural labor exchange are evident. Sales of surplus crops are uncommon and non-farm incomes are low, so farmers do not have cash to pay wage laborers. Landholding is widespread and population centers are distant, making wage laborers scarce. As noted by sociologists, labor exchange may offer the only means for gathering a labor force larger than the immediate household in this setting (Moore, 1975; Geschiere, 1995). Underdeveloped credit and labor markets, with high transaction costs for market-based exchanges, provide a significant motivation for agricultural labor exchange in these areas. Similarly, where commercialized farming is more prevalent and a landless labor force exists, we expect the prevalence of labor exchange to decline as wage labor becomes more affordable relative to the time costs of organizing exchange labor teams.

A review of the evidence on the prevalence of labor exchange teams provides some support for the hypothesis that credit rationing and high labor market transaction costs are responsible for the use of exchange labor. However, other evidence indicates the limitations of this argument. For example, the two activities in which exchange labor is most commonly used are planting and harvesting. Credit market constraints may be important contributors to exchange labor demand during planting, but they cannot explain its use during harvesting activities, when laborers can be paid immediately with a share of the output or soon afterward when crops are sold. Also, Stone (1996) and others provide important examples in which labor exchange teams operate simultaneously with wage labor and in areas that appear to be well along the path toward economic development.

In order to reconcile the evidence, we consider the other primary motivations for agricultural labor exchange, which derive primarily from technological benefits associated with returns to teamwork and from effort incentives. Two motivations for labor exchange teams that derive from benefits to teams in agricultural production include what Erasmus (1956) refers to as 'time and weight'. 'Time' concerns the need for fast completion of time-sensitive tasks (see also Moore, 1975; Goethals, 1967). Transplanting rice seedlings and planting of certain vegetables requires careful water management that dictates that the task be completed within one day. Gains here derive from reducing the duration of agricultural activities. 'Weight' refers to classical returns to the number of workers, which can be important for moving large or cumbersome objects (see Moore, 1975; Weil, 1973). One example is land clearing, where teamwork simplifies the task of moving large logs and reduces the need to cut the timber to a size manageable for one person to move. Another example concerns a team-oriented technique for planting rice, as described somewhat sardonically by Hudson and Hudson (1967) for farmers in Central Kalimantan, Indonesia:

> In the actual planting work, the men form a row and go back and forth across the field, punching holes in the ground with dibble sticks. Following close behind comes a second row composed of gossiping women, jostling children, and a few unmarried men…. The people in this second row cast rice seed into the dibble holes. (p. 103)

Many of the timing advantages of labor exchange derive from improved *scheduling* of the activity within the season, combined with the benefits of shorter task *duration* mentioned above. However, scheduling benefits accrue with *ex ante* uncertainty about the precise timing of task completion. For example, if there are efficiency gains from planting a crop as soon as the rains begin, labor exchange offers team members a lottery over completing this task as close to the start of the rains as possible (Swindell, 1985; Worby, 1995). This scheduling benefit of labor exchange is similar to the benefits enjoyed by members of rotating savings and credit associations (ROSCAs), as modeled in Besley et al (1993, 1994). ROSCA members saving for a large purchase pool their savings at regular intervals, allowing one member to make the purchase at each interval, and sooner than if he had waited until he had saved enough money on his own. This motivation for labor exchange is explicitly recognized in one of the names for labor exchange in Indonesia, *arisan kerja*. *Arisan* is the word in Bahasa Indonesia, the national language, for rotating savings schemes and *kerja* is the Bahasa word for work.

In the case of irrigated farming, the scheduling benefits of labor exchange can be combined with the timing of access to irrigation. If each farmer has access to local wells on a different day, exchange labor and water deliveries can be coordinated so that the team plants each plot on the day it receives its water. Another potential advantage of improved scheduling derives from a shorter growing season. Team members whose plots are planted early will be able to harvest their crop sooner, increasing the opportunities to grow another crop or to rent the land. This advantage is likely to be greater for irrigated fields, where the timing of the growing season is not as dependent on the rains.

These scheduling benefits to labor exchange are limited in their ability to mitigate common risks within the team. In the first case discussed above, labor exchange reduces the risk from the timing of rains by providing a lottery on which farmers can get their fields planted closest to the optimal period. However, a similar common risk such as crop spoilage due to heavy rains just prior to harvest cannot be reduced through labor exchange. In this case, a risk averse farmer will prefer to harvest as much of his crop as possible in autarky rather than join a labor exchange team and risk losing everything.

Many researchers cite the psychological and motivational benefits from working with others as motivation for labor exchange (Moore, 1975; Goethals, 1967; Geschiere, 1995). Anthropologists characterize this effect as an inducement derived from the social or festive nature of the work. Another interpretation that has received less attention is the strength of incentives created by the immediate reciprocity of labor traded. The sources of incentives to supply effort in exchange labor include individual reciprocity, group monitoring, and repeated interactions. On the first plot in a labor exchange rotation, each team member has an incentive to work hard in order to encourage similar effort from the host in subsequent rounds due to individual reciprocity. Group monitoring leads to both direct incentive effects and signaling effects. Group monitoring directly encourages effort in each round because team members do not want to be reported as shirking to the host. In addition, by working hard a team member sends a signal to other non-hosting team members about his desire to exchange a high level of effort. Each of these sources of incentives decline in later rounds because team members who have already hosted have no immediate inducement to supply effort. In a game-theoretic framework, a farmer who has already hosted in a one-time labor exchange has no incentives to supply effort on his teammates' farms. This is where repeated exchanges become important. Because team members usually come from the same village or kinship group, each member has a high probability of future exchanges with other members of the team, either through subsequent labor exchanges or other transactions. These repeated game or reputation effects may also be an important source of incentives. In this way, reciprocity and reputation can mitigate against shirking by non-hosting team members who otherwise have low incentives to supply effort because they are not the residual claimant. Reseachers who highlight the motivational benefits of teamwork often ignore other incentive problems that arise in teamwork. Because labor exchange arrangements typically involve teams of moderate size, they are also subject to the same difficulties of monitoring effort that arise elsewhere in teams. However, because the benefits of team effort accrue to only one team member, the host farmer, at each turn in the rotation, labor exchange teams do not suffer from the same weakening of incentives that arises in output pooling teams.

Finally, Geschiere (1995) emphasizes the cultural underpinnings of labor exchange, particularly norms about sharing, mutual help and contributions to social welfare. If these non-economic motivations for participation in labor exchange are significant, the prevalence of labor exchange may persist in even where there are active labor markets and little gain from teamwork.

There are few attempts in existing literature to integrate these motivations for labor exchange teams. Erasmus (1956, 1961) provides some indications of which motivation should dominate for certain activities. Overall, these discussions are limited and qualitative in nature. Nonetheless, there is considerable debate about the changing prevalence of labor exchange during the process of development. Based on the relative prevalence of labor exchange in subsistence agricultural settings, Erasmus (1956) argues that labor exchange will decline during development as market transactions replace barter or exchange transactions of all kinds. Others claim that this process will lead to the eventual demise of labor exchange altogether.

The decline of labor exchange during the development process is consistent with early models of the organization of agricultural production develop by von Thünen (1826) and Chayanov (1925). In von Thünen's model of an "isolated state", land use patterns are determined by location, with intensity of cultivation rising with proximity to a population center at the village level or proximity to the residence at the farm level. The intensity of labor use is similarly affected. If development is accompanied by reductions in transportation costs, von Thünen's model would predict greater labor intensity, which would presumably operate through the market. Chayanov (1925) describes a process of increased mechanization and commercialization of agriculture that leads to a move away from subsistence toward commercial farming, with more labor and land transactions, the development of a landless labor force, and growth of non-farm incomes. The occurrence of labor exchange in subsistence settings is also consistent with claims by Coase (1937) and Williamson (1979, 1986) that non-market institutions develop to substitute for market transactions until market trades become affordable.

Whether exchange labor is ultimately supplanted by increased commercialization of factor and output markets depends on the costs and benefits to each transaction and the possibility of an equilibrium in which they can coexist. Kranton's (1996) model of reciprocal exchange describes the conditions under which exchange transactions can persist in the presence of anonymous market exchange. In an economy with limited market transactions, search costs for market-based transactions are high. Individuals engage in repeated exchange transactions, strengthening reciprocity and reducing the risk of future reliance on exchange. However, the presence of a spot market offers an alternative to those engaged in an exchange relationship. As markets grow, a potential customer sees growing numbers of suppliers in the market, which reduces the punishment costs of reneging on a reciprocal exchange. A socially efficient equilibrium is one in which only one of these modes of transactions exist because the two have negative external effects on each other. Kranton shows that reciprocal exchange is more efficient when goods or services traded are close substitutes, but that market exchange dominates otherwise. However, when the division of transactions between the two modes of exchange is endogenous, inefficient equilibria can arise in which a large spot market makes exchange transactions unenforceable or successive repeated exchanges drive up spot market search costs. Kranton's model can help explain both the demise of labor exchange and its persistence in the presence of a functioning wage labor market. In an example of the latter case, search costs for hired labor during peak periods of labor demand can foster continued exchange labor transactions in areas where uniformity of crop mix and the timing of activities make labor substitutable across farms.

1.4 Purpose and Contribution of this Research

The presence and persistence of the institution of labor exchange has important implications for research on the performance of rural factor markets and therefore on rural development. If labor exchange arises primarily as an institutional response to imperfections in rural labor and credit markets, then the prevalence of labor exchange in a region provides an indicator of the depth of factor markets there. Accordingly, reliance on exchange labor should be accounted for in analyses of the welfare costs of market failure or the potential benefits of the commercialization of agriculture. Under this "market imperfections hypothesis," the importance of labor exchange should fade as markets develop and transaction costs are reduced. If, on the other hand, technological considerations relating to teamwork dominate the decision to use exchange labor, demand for this institution will be closely related to the characteristics of local production (e.g., crop choice, water use) and may persist even as markets develop.

Although labor exchange has existed for centuries and in many regions of the world, it has received almost no attention from economists. This oversight cannot be due to the infrequency of labor exchange. In the sample of Indonesian farmers used for this research, nearly 15 percent of farm households use labor exchange, while 18 percent use sharecropping, a land-labor institution that has received substantial attention from economists. Sociologists, anthropologists and demographers have provided considerable documentation of the existence, design and operation of labor exchange teams. In a few cases, their research has included detailed accounts of possible economic motivations for labor exchange. However, these motivations have never been subjected to a rigorous economic analysis. In particular, there is no existing theory to explain the use of agricultural labor exchange. The models of ROSCAs by Besley et al (1993, 1994) can be adapted to explain some of the benefits of labor exchange, but divorced from the context of agricultural production, possible returns to teamwork, and competition with market-oriented substitutes. Kranton's (1996) model provides a compelling explanation for how labor exchange, as a reciprocal exchange transaction, can coexist with a spot market for labor. However, this issue warrants more attention in the specific context of agricultural labor exchange. In addition, there is very little quantitative data documenting the use of exchange labor. Some quantitative evidence may exist in the large number of agricultural household surveys conducted over the last forty years. If so, these data have been ignored. Moreover, there is no quantitative analysis of farmers' decisions to participate in labor exchange.

From the existing literature, it is difficult to assess the relative strengths of each of the explanations for labor exchange described above. The primary contribution of this thesis is to provide a more rigorous assessment of these motivations by developing a formal model of labor exchange and testing the theory using primary data on farm households in Indonesia. In the theoretical model, an agricultural household decides whether to participate in labor exchange given a production technology with positive returns to teamwork, possible rationing in the credit market, and transaction costs for labor transactions. In addition, paid and exchange labor are subject to moral hazard and must be supervised in order to be productive.

From this model it is possible to contrast the technology-based explanations for labor exchange with arguments based on market failure. Results show that returns to teamwork are a necessary condition for labor exchange when non-household labor exhibits moral hazard. Labor time employed on farm through labor exchange must be reciprocated with household labor time off farm. This results in a net decline in effective labor hours on farm due to supervision costs arising from moral hazard. The inability of labor exchange to increase labor hours on farm makes it a limited substitute for market labor, effectively substituting only for team labor demand from the market. Therefore, market transaction costs alone cannot explain the use of exchange labor. However, where labor and credit markets have failed, exchange labor will be more common. The model also predicts that the effect of endowments (including farm size, household size, and asset holdings) and local labor market conditions (such as the size of the labor force and wage rates) on the decision to use labor exchange will differ systematically depending on whether the household is constrained in its holdings of working capital. Endowments, for example, will play a larger role for households that are working capital constrained. Results also show how the interplay of these market imperfections and technological determinants of labor exchange help to explain both the prevalence and persistence of this institution in developing countries.

The model developed here is a generalization of the models of the organization of agricultural production by Eswaran and Kotwal (1986) (following Roemer (1982)) and Carter and Zimmerman (2000). An important implication of the multiple market failures in these models is that the distribution of land (and capital) endowments determines the resulting organization of production as defined by the pattern of labor use. Stark predictions are derived concerning how households can be classified in an activity continuum, moving from being wage laborers, to laborer-cultivators to self-sufficient in labor use to employer-cultivators as access to capital increases. A secondary contribution of the theoretical model is to demonstrate the effect of labor exchange and returns to teamwork on the organization of production. The presence of labor exchange adds another dimension to the organization of production that interrupts this stark classification, so that activity choice is not uniquely determined by farm size. Returns to teamwork make it optimal for farmers to enter both sides of the labor market, hiring in and hiring out labor for the same activity. This practice is explicitly ruled out in the models of Eswaran and Kotwal (1986) and Carter and Zimmerman (2000) and Feder (1985), but there is empirical evidence that such a practice exists.[13] By accounting for this empirical regularity, this paper completes the "class structure" derived by Eswaran-Kotwal.[14]

One of the predictions of the Eswaran-Kotwal model is that due to multiple market failures redistribution of land endowments can lead to improvements in efficiency. Results in this paper suggest that a significant limitation of the institution of labor exchange in this respect is that it preserves the *status quo*, since all team members must

[13] In the Indonesian data, for example, there were 5128 observations on households hiring in labor by season and activity, where activities were coded as land preparation, plowing, planting, weeding, harvesting, or milling. For 14.7 percent of these observations, household labor was also supplied off farm during the same period of activity.

[14] Of course, other reasons for the practice exist. Sadoulet, de Janvry, and Benjamin (1998) suggest that intrahousehold specialization could lead a household to enter both sides of the labor market as highly

have access to land and differences in yields arising from heterogeneity in land quality are not pooled within teams.

The empirical portion of the dissertation tests the assumptions and predictions of the model of labor exchange using the 1998-99 Indonesian PATANAS survey, an agricultural household data set that I helped collect. I first estimate a production function to test for returns to teamwork for the subsample of rice and corn farmers that represent the most likely pool of participants in labor exchange teams. Empirical evidence of a productivity advantage to team production is relatively rare (see Hamilton, Nickerson and Hideo, 2003; Leibowitz and Tollison, 1980), particularly so in agriculture. The estimation procedure separates out the incentive effects inherent in the piece rate and output share contracts that are more common under team production from the pure team effect. The results provide evidence of substantial returns to teamwork for this sample of farmers.

The model of labor exchange predicts that the importance of endowments, transaction costs, and market conditions in the decision to use labor exchange depends critically on whether the household is working capital constrained, which is unobserved. The empirical strategy presents several alternative formulations of an empirical model to investigate how different divisions of the sample into working capital constrained and unconstrained regimes affects the model's ability to explain predicted behavior. First, I assume that all households are working capital constrained and consider how the level of

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educated household members attract higher wages off farm while the household hires unskilled labor on farm.

working capital holdings affects the probability of participating in labor exchange. Next, I consider alternative informed, but arbitrary, divisions of the sample into working capital constraint regimes based on the observed level of working capital holdings. This model allows the parameters in the decision to participate in labor exchange to differ for working capital constrained and unconstrained households. The model estimated is an endogenous switching regression model in which assignment of households into constrained and unconstrained cohorts is assumed, and where error terms across equations are correlated. Finally, I estimate the parameters of the switching regression model with unobserved sample separation using the EM algorithm, which treats unobserved regime assignment as a missing data problem. The algorithm exploits the relationship between the model with unobserved and observed sample separation to obtain maximum likelihood estimates for the missing data problem. Such a regime switching model can be difficult to estimate, particularly when the dependent variable of interest (in this case, the decision to use labor exchange) is discrete. The EM algorithm makes it possible to obtain improved estimates with some interesting implications for determinants of labor exchange participation.

The empirical results lend broad support to the model of labor exchange developed here. When the entire sample is treated as working capital constrained, the relationship of working capital holdings to the probability of using labor exchange has an inverted U shape, as predicted by the model of labor exchange. At low levels of working capital, farmers operate as laborer cultivators and use additional liquidity to expand operated area, increasing demand for team labor through labor exchange. Farmers with higher working capital holdings are autarkic in labor use or are net hirers of labor. For this group, an increase in working capital holdings can reduce the probability of using labor exchange by making market labor alternatives relatively cheaper. When only households with no working capital holdings are treated as constrained, land endowments and household size affect the probability of using labor exchange in a manner consistent with the model for constrained and unconstrained households. Also, maximum likelihood estimates obtained using the EM algorithm show that working capital holdings have no effect on the probability of using labor exchange for unconstrained households, as the model suggests. Among other results, the roles of transaction costs and technology as labor exchange determinants are also confirmed by these estimates. One of the most significant determinants of participation in labor exchange is the cost of finding teammates, which is a function of the distribution of land within a village. Results show that the probability of a farmer joining a labor exchange team increases sharply with the number of other plots in the village similar in size to his plot. Use of simple pump irrigation has a positive effect on use of labor exchange. The results suggest that labor exchange use is compatible with low-level irrigation technology, but is not relevant where more technical irrigation is employed.

The rest of this dissertation is organized as follows. Chapter 2 presents the model of labor exchange and demonstrates the relationship between returns to teamwork, labor and working capital constraints, and the decision to use labor exchange. In Chapter3, I introduce the data and investigate the use of labor exchange for this sample of Indonesian farmers. Chapter 4 develops and tests an empirical model of the farmer's decision to use labor exchange based on the model from Chapter 2. The implications of the estimation results for the model of labor exchange use are discussed. Concluding remarks are found in Chapter 5.

2 A Model of Labor Exchange with Imperfect Factor Markets

2.1 Introduction

In this chapter, I develop a model of a farmer's decision to use labor exchange. Labor exchange is characterized by the simultaneous demand for labor on-farm and supply of labor off-farm, with neither transaction involving a payment. The model demonstrates how returns to teamwork and imperfections in the labor and credit markets affect the decision to use labor exchange. It also accounts for the effect of a productivity advantage for household labor on farm, attributed to moral hazard, on the exchange labor decision. In this model, the decision to participate in labor exchange is a function of resource endowments, team production technology, and three possible sources of market imperfections: constraints on working capital, moral hazard in non-household labor, and search costs for all labor transactions.

The theoretical framework developed here applies and extends existing models of the organization of agricultural production, especially Eswaran and Kotwal (1986), but also Feder (1985) and Carter and Zimmerman (2000). These models demonstrate that multiple market imperfections lead to patterns of orientation toward the labor market in terms of net labor demand that vary systematically with access to capital. Due to rigidities in factor markets, an optimizing farmer's endowments of working capital, or equivalently land in Eswaran and Kotwal, completely determines his mode of production: whether he works some time off-farm, cultivates in self-sufficiency, or hires labor on-farm, conditional on a constant returns to scale production technology. These papers formalize earlier models of the organization of agriculture. Eswaran and Kotwal (1986) base their model on Roemer's (1982) analysis of class structure in which agents are classified by their activities according to their access to the means of production. Much earlier, Chayanov (1926) recognized that whether labor is hired in or hired out depends on land endowments when credit and land market imperfections make it impossible to adjust operated area to account for household size:

> We see that, proportionately, as land is insufficient and becomes a minimum factor the volume of agricultural activity for all farm elements is reduced…But the work hands of the farm family, not finding a use in farming, turn, as we will see below, to crafts, trades and other *non-agricultural* earnings to attain the economic equilibrium with family demands not fully met by farm income or by receipts from crafts and trades. (Chayanov, 1926, p. 94, italics in original).

This class of models provides the framework needed to address a farmer's decision to participate in labor exchange. By allowing for the possibility of positive returns to teamwork, I can investigate how the two primary explanations for labor exchange, teamwork and factor market imperfections, interact to determine labor exchange use as an alternative labor arrangement not considered by the other models.

I generalize these earlier models by allowing for the possibility of returns to teamwork and for non-market exchange of factors through labor exchange. Returns to teamwork make it profitable for a farmer to work off farm as a means to gain access to labor on farm, either by entering the labor market to finance hired labor on farm or through labor exchange. As shown below, this establishes returns to teamwork as a necessary condition of labor exchange. In the models by Eswaran and Kotwal and Carter and Zimmerman, supervision costs due to moral hazard make simultaneously buying and selling labor unprofitable, a key simplification in the classification of households according to activities. The model developed here offers returns to teamwork as an explanation for this common practice and interrupts the tidy classification of households into modes of production determined entirely by land endowments. Moreover, with returns to teamwork, optimal labor activities are determined not only by endowments of land, and therefore capital, but also by the household's labor endowment. This increases the explanatory power of the model, making it consistent with Chayanov and with the models of Benjamin (1992) and López (1984). Indeed, Benjamin uses the sensitivity of labor supply to household size as a test of labor market imperfection.[15]

The model also demonstrates that returns to teamwork are not sufficient to explain labor exchange, even in the presence of working capital constraints. Under returns to teams, a farmer with limited cash holdings can work in the labor market to pay for hired workers on farm. Labor exchange arises when labor market imperfections rule out such transactions. I model these imperfections as transaction-specific per-unit costs to buying, selling, or exchanging labor. These can be interpreted as search costs for finding market laborers, off-farm employment, or exchange labor teammates, respectively. The analysis yields conditions on these transactions costs that determine when each activity will be observed. In the resulting generalized classification of the organization of agricultural production, the modes of production are determined not only by access to capital, but also by the team production technology and by transactions costs in the labor market.

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[15] Although Benjamin cannot reject that labor supply is independent of household size for a sample of Javanese farmers, this does not weaken the saliency of the theoretical result. Close proximity of his sample

Another implication of the model is that demand for labor exchange is a function of endowments of land, capital and household size only when both working capital and labor market constraints are binding. This endowment sensitivity of the mode of production is a central feature of the multiple-market failures in the models by Eswaran and Kotwal, Feder, and Carter and Zimmerman. It leads to a series of testable predictions on the effect of endowments on demand for labor exchange that can be used to validate the classification of households into working-capital–constrained and –unconstrained cohorts for the sample of Indonesian farmers studied in the empirical work that follows. The model also generates hypotheses about how labor exchange, as a non-market form of exchange, responds to changes in the wage rate, the price of the market alternative. Tests of these results in forthcoming chapters lend considerable support the theoretical model developed here.

The effect of teamwork on the organization of production has received increased attention after the seminal works by Marschak (1955), Marschak and Radner (1972), Groves and Radner (1972) and Groves (1973). However, their treatments focus on the effects of private information on team operation and the optimal incentive structure for team production. Lazear (1998) describes three economic motivations for teamwork in production: (i) complementarities arising from joint production by workers, (ii) returns to specialization, and (iii) gains from knowledge transfer by workers with privately held information about the production process. The labor exchange teams modeled here are primarily taking advantage of the first motivation for teamwork identified by Lazear.

to major urban centers could explain Benjamin's failure to reject labor market perfection.

These teams are consistent with labor teams discussed by Rosen (1986), in which the benefits of teamwork derive from simultaneous work activity by multiple, possibly homogenous, workers. The agricultural work involved is typically homogenous and repetitive, so gains from specialization are small. Also, the private information held by team members is not as important as in the works by Marschak, Radner and Groves because the work is coordinated and performed jointly. Other research on the significance of returns to teamwork in labor decisions has considered how team production technology, modeled as a coordination requirement, affects work schedules and market wages (Deardorff and Stafford, 1976; Weiss, 1996; Fitzgerald, 1998). The analysis here shows that returns to teamwork may have even broader implications for labor markets by providing an impetus for development of a significant non-market labor institution when labor markets fail.

Gains from teamwork also featured prominently as a motivation for the hierarchical relationship between employer and employee when the employee is subject to moral hazard in the seminal paper by Alchian and Demsetz (1972). In this relationship, the employer, who is the residual claimant, is required to serve as principal in order to monitor the employee and reduce shirking. Holmström (1982) argues that no monitoring is required but that the employer is needed to break the budget in order to eliminate the incentive to shirk. The fundamental role of the employment relationship in both of these papers is to assign residual claimancy in order to eliminate shirking that characterizes team production when output is pooled. In this context, labor exchange provides an interesting alternative solution to the moral hazard problem in output pooling teams.

Rather than pooling output, labor exchange team members pool their labor and reduce the incentive to shirk by assigning the role of residual claimant in each round of the rotation. Moreover, labor exchange arrangements may provide stronger effort incentives than the standard employment relationship. Rotating the employer role boosts effort incentives by adding reciprocity to the effort exchange. In addition, non-hosting members have an incentive to monitor their teammates in order to gain information about their performance in future rounds.

Imperfect access to market labor has featured prominently in agricultural household models and has mixed empirical support. Lewis (1954) developed the classical model of labor market dualism for economies characterized by surplus labor. Other models of underemployment include Stiglitz (1982) and Bardhan (1984). Various sources of labor market failures have been used to explain the downward rigidity of wages in the presence of underemployment in models of efficiency wages (Leibenstein, 1957; Mirlees, 1975; Stiglitz, 1976; Bliss and Stern, 1978a, 1978b). Empirical evidence mostly supports the presence of labor market imperfections in rural developing economies (Jacoby, 1993; Skoufias, 1994; Bowlus and Sicular, 2003). Exceptions have been found primarily in regions with significant employment opportunities (Binswanger and Rosenzweig, 1984; Bowlus and Sicular, 2003). Benjamin (1992) tests for rationing of hours worked in the labor market in a model of households' off-farm labor supply for Indonesian rural farm households on Java. He also tests for two other sources of labor market imperfections incorporated in the model presented here: constraints to hiring labor on-farm and different efficiencies of family and hired labor. Benjamin emphasizes that these alternative labor market imperfections are not mutually exclusive. Constraints to labor transactions may coexist with moral hazard for hired labor. Also, households may face tight labor markets for hiring-in during the peak season and slack markets for off-farm employment in the slack season. The model I present here differentiates between these sources of labor market imperfections because they have different implications for when labor exchange will arise as an alternative to market labor.

In this chapter, I develop the model of a farmer's decision to use labor exchange as a function of endowments, production technology and factor market constraints. I demonstrate how the possibility of returns to teamwork generalizes the potential set of observed activities with respect to the labor market and creates the potential for labor exchange. I then present the effects of this generalization on the modes of production identified by Eswaran and Kotwal. This theoretical result is developed because the effects of endowments and prices on the demand for labor exchange depend on the size of the endowments and on which set of constraints is binding, the determinants of the modes of production. After establishing this intermediate result, I systematically explore how working capital, farm size, household size and wage rates affect the labor exchange decision for farmers using different modes of production. Through this approach, I am able to explain the role of teamwork, factor market imperfections, labor market conditions and the distribution of land in the decision to use exchange labor.

2.2 A Model of Labor Exchange

Production is a function of land and labor. At the beginning of each season, households have an endowment of land, $\overline{A}$, and a labor endowment determined by the number of household members, $\overline{n}_H$, with total household labor time given by $T\overline{n}_H$, $T \geq 1$. Labor time on farm comes from three sources, household labor time on farm, *H*, and external or non-household labor time on farm, *L*, which can be hired in the paid labor market or through labor exchange. In order to highlight the role of teams, consider labor time by source as a function of the number of workers, $H = h_H \overline{n}_H$ and $L = h_M n_M + h_E n_E$, where h_i and n_i are hours per worker and number of workers, respectively, for the *i*th worker type, *i*=*H*,*M*,*E*. For simplicity, assume hours per worker for external labor is set by convention and normalized to one, $h_M = h_E = 1$.[16] This makes it possible to summarize the demand for external labor on farm by the number of market and exchange labor workers, so that $L = n_M + n_E$. The size of the labor team working on the farm is the sum of the number of paid laborers, exchange laborers, and household members, $N = n_M + n_E + \overline{n}_H$. [17]

[16] One interpretation of this assumption is that, for technological reasons, the period over which external labor is needed is fixed and the farmer only needs to decide how many workers to employ. This would be the case if use of external workers is required only for labor-intensive tasks, and the time sensitivity of these tasks require that they be completed in a specific number of days. This is a reasonable depiction of labor demand for planting irrigated rice, for example, in the sample area in the Indonesian data used here.

[17] By the normalization used here, n_i, *i*=*M*,*E*, represents both the number of workers and the number of hours secured on farm through the *i*th labor arrangement. Because each household member is endowed with $T \geq 1$ units of time, n_H represents only the number of household members.

In order to allow for the possibility of returns to teamwork in production, the production function takes the form

$$(2.1) \qquad f(A, H + L, N),$$

where A is area planted (which may be greater than or less than $\overline{A}$); and labor team size enters the production function as a separate argument from total labor time used on-farm. The production function is increasing in land and labor time, is linearly homogenous, strictly quasiconcave, and twice continuously differentiable in each of its arguments with $f_{ij} > 0, \ \forall\, i \neq j$.[18] The last assumption assures that all pairings of inputs are substitutes. Also, both land and labor are essential inputs: $f(0, H + L, N) = 0$, $f(A,0,0) = 0$. In this specification, returns to teamwork arise as an additional, incremental effect of team size on output independent of total labor time. I define "returns to teamwork" by the sign of the partial derivative of the production function with respect to its third argument, f_3. I assume the production function is concave in team size, with f_3 positive, zero, and then negative as team size increases, corresponding to positive, zero and negative marginal returns to teams, respectively. With zero marginal returns to teams, team size has no effect on output independent of its effect through labor time and the production function behaves in a more classical manner with output a function of area and labor time. However, this specification of the production function is justified whenever labor time

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[18] Subscripts on functions denote partial derivatives with respect to the argument(s) listed. For example, $g_i = \partial g(x_1,..., x_n)/\partial x_i$ and $g_{ij} = \partial^2 g(x_1,..., x_n)/\partial x_i \partial x_j$.

per worker is not perfectly substitutable for number of workers, which may be common in practice.[19] A similar specification of the production function has been used elsewhere to model the effects of team production on work schedules and employment (Fitzgerald, 1998).[20]

Modeled in this way, returns to teamwork are most easily interpreted as arising from returns to team size. This simplification focuses the discussion while still providing some context for general returns to teamwork. As described in detail in Chapter 1, there are many sources of efficiency gains from team production. In addition to classical returns to the number of workers, the benefits of teamwork include returns to specialization, increased motivation, shorter duration of time-sensitive tasks, and improved scheduling of tasks. Many of these sources of returns to teamwork are concave in team size, and so are captured implicitly in the model developed here. Returns to team production arise in many agricultural settings, where coordination of activities by multiple workers allows tasks to be completed more quickly, more efficiently, and with less monotony.

External laborers secured either from the paid labor market or through participation in a labor exchange team are subject to moral hazard. In this model, moral hazard arises because realized output is a noisy signal of input use,

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[19] For example, if team size has no marginal effect on output independent of labor time $\left(f_3 = 0\right)$, then hours per worker and number of workers are perfect substitutes and a one unit decrease in, say, n_H, can be exactly offset by a one unit increase in h_H. However, if there are positive returns to teamwork $\left(f_3 > 0\right)$, then output increases by reducing h_H by one unit and increasing n_H by one unit.

(2.2) $$q = \varepsilon f\left(A, H + L, N\right),$$

where ε is a random production coefficient with expected value one, representing unobserved stochastic determinants of production. The presence of ε implies that the farmer cannot identify the level of q, A, L, or N simply by knowing the other three (where H is assumed known). In agriculture, a number of factors contribute to this random production coefficient. Although rainfall levels or the presence of pests is observable, the full effects of these stochastic events and their interactions on productivity are unknown to the farmer, making it impossible to infer the labor contribution. Because of moral hazard, the household must also devote time to supervising external workers, which is captured in the supervision function, $s(L)$.[21] This is one source of labor market imperfections in this model. Assume $s' > 0$, $s'' > 0$, $s(0) = 0$, and $s'(0) < 1$.[22] The latter assumption ensures that supervision costs alone will not rule out the use of external labor in the absence of returns to teamwork. The second source of labor market imperfections is search costs for all labor transactions. Labor transactions for hiring market labor or labor exchange each incur a per-head search cost, c_M and c_E, respectively, that reduces

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[20] See also Roumasset and Uy (1980), where labor quantity and effort are separate arguments of the production function, via an intermediate input function, in part to allow for team production.

[21] A more realistic characterization of the supervision function would have supervision costs declining in household size (eg, $s\left(L/\bar{n}_H\right)$). Since this detail does not substantively affect the analysis, I omit it for simplicity.

[22] Labor exchange may have stronger inherent effort incentives than the average hired labor contract, which includes a high share of low-powered time rate contracts. The characteristics of labor exchange that provide effort incentives include reciprocity (Fehr, et al, 1997; Fehr, et al, 1998), mutual monitoring of teammates (Kandel and Lazear, 1992, Dong and Dow, 1993), and reputation effects (Fudenberg and Tirole, 1991; Tadelis, 1999). If these effects are strong and monitoring technology is inexpensive (teammates work close together), then I could incorporate this distinction by modeling lower supervision costs for exchange labor than for market labor: $s'(n_M) > s'(n_E)$ for $n_M = n_E$. Incorporating these incentive differences would increase demand for labor exchange. For now, I omit this detail from the model for simplicity.

household labor time available for other activities. Similarly, household off-farm labor supply, *F*, incurs a per-member-equivalent search cost, c_F. These costs are similar to recruitment costs in Bardhan's (1979) model of wages and unemployment in an agrarian economy. Here, search costs are denominated in the time required to find the workers or the employment off farm.

The modes of production that arise are determined in part by constraints on the household's labor time and working capital. The household time constraint is

$$T\overline{n}_H - R - F - n_E - H - s(L) - c_F \frac{F}{T} - c_M n_M - c_E n_E \geq 0, \tag{2.3}$$

where each household member is endowed with $T \geq 1$ units of time. The household allocates the total time of all of its members to leisure, *R*, household off-farm labor supply, *F*, labor exchange, n_E, and cultivation on-farm, *H*. It also pays a time cost for supervising external labor on farm and as search costs for labor transactions.[23] Equation (2.3) shows that labor time obtained on farm through labor exchange must be reciprocated with an equal amount of time spent working on teammates' fields.[24]

[23] A household facing a per-head cost for entering the labor market, c_F, will have some household members specialize in market labor, so that the fewest possible number of members enters the labor market. As written in equation (3), a household member spending only a fraction of his time in the labor market pays only that fraction of the search cost. A true per-head cost would require rounding *F/T* up to the nearest integer. Ignoring this complication has little effect on the nature of the results.

[24] Because hours per worker obtained on farm under labor exchange have been normalized to one, n_E represents both the number of hours the household supplies off farm in labor exchange and the number of labor exchange workers hired on farm.

The price of land is *v* and the wage rate for market labor is *w*. Demand for factors is potentially constrained by holdings of working capital, $\overline{B}$. Sources of working capital include savings and credit. Because access to credit in rural developing economies typically requires use of land holdings or other assets as collateral, working capital is closely related to asset holdings. For simplicity, credit taken at the beginning of the season does not incur any interest charges. In order to capture the role of credit market constraints, assume credit is rationed in the sense that there is an upper bound on the amount of credit that can be obtained. A farmer can also obtain liquidity during the season by working off farm $(F > 0)$ or renting out land $(A < \overline{A})$. Farm income is not a source of liquidity because it is not earned until the end of the season.[25] Based on these sources of liquidity, demand for land and market labor are subject to the working capital constraint

(2.4) $$\overline{B} + wF + v\overline{A} \geq wn_M + vA.$$

The constraint requires that farm expenditures on paid labor and land rentals cannot exceed working capital, off-farm labor income, and the value of owned land. Because land can be leased in or out, area cultivated is determined by this constraint on working capital. Labor exchange does not enter the working capital constraint because it does not earn or cost liquidity.

[25] Although labor income may be earned at any point the season, I implicitly assume that workers can borrow (costlessly) against this income at the beginning of the season. Eswaran and Kotwal (1986) suggest that consumption loans by employers may be justified if workers have subsistence consumption levels and

All households have identical preferences over income, *Y*, and leisure and utility is additive in income and the utility derived from leisure,

(2.5) $$U(Y,R) = Y + u(R),$$

where $u' > 0$, $u'' < 0$, and $u'(0)$ is infinite. The marginal utility of leisure is infinite when $R = 0$, so that some time is always reserved for leisure. Assuming endowments of $\bar{A}$ are large enough that cultivation is profitable $(A > 0)$, the farmer maximizes household utility, (2.5), subject to constraints (2.3) and (2.4) and non-negativity constraints on the remaining choice variables:[26]

(2.6)
$$\underset{A,R,F,n_m,n_E}{Max} \; f(A, H + L, N) + wF - v(A - \bar{A}) - wn_M + u(R)$$

$$\text{s.t.} \quad H \equiv T\bar{n}_H - R - F - n_E - s(L) - c_F F/T - c_M n_M - c_E n_E \geq 0,$$

$$\bar{B} + wF + v\bar{A} \geq wn_M + vA,$$

$$F \geq 0, \; n_i \geq 0, \; i = M, E.$$

By the assumptions on $u(R)$, leisure always yields positive marginal utility, so the time constraint in (2.3) always binds. The model in (2.6) incorporates this fact, with the time constraint rewritten so that household labor time spent on farm, *H*, is the residual time category. Therefore, the first constraint in (2.6) is a non-negativity constraint on

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consumption affects productivity (see Foster and Rosenzweig, 1994). However, the presence of such loans increases incentives for morally hazardous behavior.

household labor time on farm. It is determined during optimization by the selection of the other choice variables. This simplifies the analysis by making it possible to substitute the time constraint into the production function. By the concavity of $U(Y,R)$ and the quasiconcavity of $f(A,H+L,N)$, the optimization problem in (2.6) has a unique solution. The Lagrangean and first-order conditions for this problem are provided in the Appendix equations (A1). The Kuhn-Tucker multipliers for the first two constraints are μ and λ, respectively. The solution to the problem in (2.6) is a vector including farm area operated, leisure and labor supply and demand, each as a function of prices, *v* and *w*, and endowments, $\overline{B}$, $\overline{A}$, and $\overline{n}_H$.

2.3 The Organization of Production

The availability of labor exchange and the possibility of returns to teamwork generalize existing models of the organization of agricultural production. The models of Eswaran and Kotwal (1986), Feder (1985) and Carter and Zimmerman (2000) all rule out a mode of production in which working-capital constrained households simultaneously hire in and hire out labor (i.e., $n_M > 0$, $F > 0$). The rationale is that supervision costs for hired labor drive its shadow price above the market wage, making it unprofitable for a farmer to enter the labor market in order to finance labor expenditures at home. However, with positive returns to teamwork, entering both sides of the labor market can be optimal.

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[26] I normalize output prices to one and ignore discounting of farm income earned at the end of the season.

Lemma 2.1: When external labor exhibits moral hazard, returns to teamwork are a necessary condition for simultaneously hiring and supplying labor in the market.

Proof:

Assume $n_M > 0$, $F > 0$. By (A1.b)-(A1.d),

(2.7) $$f_3 = \mu + u'(s' + c_M + c_F / T) > 0.$$ Q.E.D.

According to the equilibrium condition in equation (2.7), a farmer can take advantage of returns to teamwork by financing hired labor on farm with household labor supplied off farm. At the optimum, the farmer undertakes the two activities until the marginal returns to teamwork equal the marginal cost of both finding and supplying off-farm work and recruiting and supervising hired workers on farm. Bardhan (1982) identified contractual indivisibilities, specialization and land fragmentation as reasons why farmers may simultaneously buy and sell labor. Sadoulet, de Janvry and Benjamin (1998) develop a model with heterogeneous household labor in which skilled household members specialize in non-agricultural labor off-farm while other family members hire unskilled labor to replace them on farm. Here, I add returns to teamwork as another possible motivation for this common practice.

A corollary to Lemma 2.1 is that a necessary condition for labor exchange is returns to teamwork.[27] Substituting (A1.b) into (A1.e), the analogue to equation (2.7) for labor exchange is

$$f_3 = \mu + u'\left(s' + c_E\right). \tag{2.8}$$

A necessary condition for participation in a labor exchange team is that the marginal returns to teamwork equal the marginal cost, measured by the shadow value of household labor time spent on teammates' farms plus the marginal disutility of time spent supervising and coordinating exchange labor. For farmers that also devote some labor time to their own crops $(H > 0)$, equation (2.8) can be rewritten as $f_3 = f_2\left(s' + c_E\right)$. This form of the equilibrium condition shows that demand for labor exchange derives entirely from demand for team labor, since on farm labor time is effectively lowered through labor exchange. Moreover, none of the other motivations for simultaneously hiring and supplying labor in the market can explain labor exchange.[28]

Equations (2.7) and (2.8) show that labor exchange implies behavior that is identical to simultaneously buying and selling labor in the market if the two arrangements have the same search costs. Because neither activity draws down liquidity, each offers a means of taking advantage of returns to teamwork for working capital constrained households that cannot hire a paid labor team out of savings or on credit. However, the joint use of both

[27] This corollary is proven by inspection of (A1.e).
[28] The only possible candidate is specialization. It is possible that farmers pool their labor through labor exchange to trade specialized skills. However, evidence from Indonesia and sociological literature for

of these labor arrangements, while narrowly theoretically possible, is empirically unlikely so I rule it out.

Lemma 2.2: A farmer cannot simultaneously sell labor, hire market labor *and* participate in labor exchange ($F > 0$, $n_M > 0$ and $n_E > 0$).

Solving (2.7) and (2.8) together shows that a necessary condition for $F > 0$, $n_M > 0$ and $n_E > 0$ is

(2.9) $$c_E = c_M + \frac{1}{T} c_F \,.$$

If the time cost of organizing a labor exchange team is identical to the combined cost of hiring labor and of finding work for household members in the labor market, a household may engage in all of these transactions simultaneously. However, this condition is unlikely to hold as a strict equality, so this mode of production is formally ruled out.

For agricultural activities that exhibit returns to teamwork, labor exchange offers an alternative to hiring a team by simultaneously buying and selling labor. Which mode of production obtains depends on the relative size of search costs for each type of labor transaction. Search costs for hiring labor through the market are likely to be high during peak periods of labor demand or where the supply of landless laborers is small.

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other countries suggests this is at most a secondary motivation for labor exchange. Most tasks performed by labor exchange are homogenous, repetitive tasks that team members perform together in unison.

Conversely, in a village characterized by surplus labor due, say, to a skewed distribution of landholdings, search costs for off-farm employment will be high. Time costs for participation in labor exchange involve finding potential teammates and agreeing to the rotation of activities on team members' farms. These costs will be high where the share of households seeking labor exchange is small or where the size distribution of farms is highly variable, since cash payments are required if the exchange of labor time within the team is not reciprocal.

A comparison of these search costs determines, in part, which combination of labor activities will be observed. If the search costs of participating in labor exchange exceeds those from financing labor purchases through labor sales ($c_E > c_M + c_F/T$), it will be more profitable for a household to enter both sides of the labor market than to use exchange labor (i.e., $F > 0$, $n_M > 0 \Rightarrow n_E = 0$). Likewise, labor exchange has an advantage if each labor transaction incurs the same cost regardless of the source, $c_E = c_M = c_F = c$, because labor exchange involves only one transaction. Generally, households participating in labor exchange that also sell labor in the market will not hire any labor (i.e., $F > 0$, $n_E > 0 \Rightarrow n_M = 0$) whenever labor exchange has lower transaction costs ($c_E < c_M + c_F/T$). In a village characterized by surplus labor, where household members have difficulty finding a paying job $\left(i.e., c_F >> 0 \Rightarrow F = 0\right)$, the simultaneous use of paid labor and exchange labor may be observed. Of course, if returns to teamwork are not large enough to cover the relevant transactions costs, none of these labor arrangements will be observed. This is a function of returns to teamwork being necessary but not sufficient for labor exchange or for simultaneous market labor purchases and sales.

These conditions on observed labor activities, like that in equation (2.9), depend on the specification of search costs as variable per-head costs of finding workers or employment. If instead these transaction costs were fixed costs for entry into labor exchange or either side of the labor market, other combinations of labor activities may be observed. However, in this model, the behavioral implications of participating in labor exchange are identical to those for simultaneously buying and selling labor in the market, so Lemma 2.2 still holds if the transactions costs are fixed costs. A farmer seeking to increase team size on his farm without reducing the stock of working capital will either use labor exchange or simultaneously buy and sell labor in the market, depending on which activity incurs lower fixed transactions costs. Another alternative specification is that search costs are declining in the number of workers employed in each type of transaction. In this case, Lemma 2.2 may not hold. However, given the farmer's need to screen each worker when external labor exhibits moral hazard, constant per-head search costs seem to be a reasonable assumption.

It is now possible to characterize the modes of production that can arise with possible returns to teamwork and the availability of exchange labor. The characterization is expressed in terms of the team technology, transaction costs, and which labor sources are at the corner solution. Accordingly, 12 distinct modes of production can be identified.[29]

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[29] Note that the necessity of labor in production requires at least one of H, n_M, or n_E to be positive.

These are listed in Table 2.1. The columns of Table 2.1 correspond to the market labor regimes identified in the classification by Eswaran and Kotwal (1986). They are ordered as the set of optimal labor activities that arise with increasing endowments of working capital or land. The rows of Table 2.1 differentiate returns to teamwork and exchange labor regimes. They are listed in increasing order of returns to teamwork by labor exchange regime determined by the relative size of labor transactions costs.

If agricultural production exhibits no returns to teamwork, we are in an Eswaran-Kotwal world, with four modes of production: *laborer-cultivators* operate their own farms and supply labor in the market; *self-cultivators* cultivate their farms in autarky; *small capitalists* operate their farm using some hired market labor; and *large capitalists* devote all household labor time to supervising hired workers. Labor exchange does not arise in this setting because of the absence of returns to teamwork. An important result from Eswaran and Kotwal is that, with imperfections in the labor and credit markets, the set of optimal labor activities depends only on endowments of working capital and land. Thus, with multiple factor market imperfections, the distribution of assets entirely determines the modes of production or, in the words of Roemer, the "class structure." I show presently that this unique correspondence of modes of production to asset endowments no longer applies when production exhibits nonlinearities due to positive returns to teamwork.[30] The addition of transaction-specific search costs for labor transactions also

[30] Kevane (1996) discusses the implications of relaxing the assumption of constant returns to scale on a similar typology of agrarian structure. Here, I obtain similar nonlinearities in the production technology while maintaining the assumption of global constant returns to scale by disaggregating the labor input into labor time and team size.

complicates the typology. Regardless of returns to teamwork, search costs could make some modes of production infeasible, shifting farmers among the columns of Table 2.1.

Table 2.1: The Organization of Production With Returns to Teamwork and Labor Exchange

Team Technology and Exchange Labor Regimes	Market Labor Regimes: laborer-cultivator	self-cultivator	small capitalist	large capitalist
No returns to teams $(f_3 = 0)$ or c_i prohibitive, i=E,M, or F				
No labor exchange $(n_E = 0)$:	$F > 0, H > 0, n_M = 0$	$F = 0, H > 0, n_M = 0$	$F = 0, H > 0, n_M > 0$	$F = 0,\ H = 0,$ $n_M > 0$
Moderate returns to teams* $(f_3 > 0)$				
No labor exchange $(n_E = 0)$: $c_E > c_M + c_F/T$	$F > 0, H > 0, n_M > 0$ $(F > n_M)$	$F > 0, H > 0, n_M > 0$ $(F = n_M)$	$F > 0, H > 0, n_M > 0$ $(F < n_M)$	
Labor exchange $(n_E > 0)$: $c_E < c_M + c_F/T$	$F > 0, H > 0, n_M = 0$	$F = 0, H > 0, n_M = 0$	$F = 0, H > 0, n_M > 0$	
Large returns to teams* $(f_3 >> 0)$				
No labor exchange $(n_E = 0)$: $c_E > c_M + c_F/T$	$F > 0, H = 0, n_M > 0$ $(F > n_M)$	$F > 0, H = 0, n_M > 0$ $(F = n_M)$	$F > 0, H = 0, n_M > 0$ $(F < n_M)$	
Labor exchange $(n_E > 0)$: $c_E < c_M + c_F/T$	$F > 0, H = 0, n_M = 0$	$F = 0, H = 0, n_M = 0$	$F = 0, H = 0, n_M > 0$	

*These modes of production arise when transactions costs are small relative to the gains from returns to teamwork.

With the emergence of returns to teamwork, eight new modes of production are possible, four at moderate levels of returns to teams and four others if returns to teams in the technology are large.[31] These new modes of production arise only if productivity gains from returns to teams are large enough to cover the search and other costs for the labor needed to take advantage of the team technology. That is, in some areas where agriculture exhibits returns to teamwork, the search costs of organizing an exchange labor team or of joint purchase and sale of market labor may be prohibitive. In these cases, only the four modes of production identified by Eswaran and Kotwal are observed despite the presence of technical returns to teamwork. I now consider the other modes of production that can arise when returns to teams are sufficiently large to overcome the transactions costs of obtaining team labor.

At moderate levels of returns to teams, the optimal solution to the farmer's problem still leads to some household labor time spent cultivating crops on-farm $(H > 0)$. These four modes of production are distinguishable by relative search costs for each type of labor transaction and endowments of working capital. If $c_E < c_M + \frac{1}{T}c_F$, labor exchange offers a more profitable mechanism for taking advantage of returns to teamwork than does simultaneously buying and selling labor in the market. One mode of production that emerges for households with small working capital endowments involves time allocated to own production, off-farm market labor supply, and labor exchange $(F > 0, H > 0,$

[31] Positive returns to team size is a characteristic of the technology that is a function of the level of the choice variables. References here to size of returns to teams concern the technological component of the marginal productivity of team size. For example, in a Cobb-Douglas functional form for the production function in (2.1), the exponent on team size is the technological parameter that determines the size of returns to teams at each level of the choice variables.

$n_M = 0, n_E > 0)$. According to the first order conditions from equations (A1.c) and (A1.e), the equilibrium condition that describes this mode of production is

$$(2.10) \qquad f_3 = \frac{s' + c_E}{1 + c_F / T}(1 + \lambda)w \, .$$

The farmer allocates land and labor to equate the marginal returns to team production from exchange labor to the marginal cost in terms of the shadow value of foregone wages, relative search costs, and supervision costs for exchange labor on farm. Similarly, farmers with larger working capital endowments and facing moderate returns to teamwork will adopt modes of cultivation analogous to the self-cultivator or small capitalist modes of production with the addition of labor exchange when $c_E < c_M + \frac{1}{T}c_F$. These modes of production are characterized by $F = 0, H > 0, n_M = 0, n_E > 0$ and $F = 0, H > 0, n_M > 0, n_E > 0$, respectively. Alternatively, if $c_E > c_M + \frac{1}{T}c_F$ with moderate returns to teamwork, a single new mode of production arises in which a cultivating farmer simultaneously hires market labor and supplies labor to the market $(F > 0, H > 0, n_M > 0, n_E = 0)$. With modes of production defined only by technology, relative transaction costs, and binding non-negativity constraints on labor activities, this single new mode of production obtains in the first three market labor regimes, across much of the distribution of working capital endowments. Within this mode of production, three cases can be distinguished by the relative amount of labor supplied off farm and hired on farm. In the face of these relative transactions costs, farmers with relatively small working capital endowments supply more labor off farm than hired on farm $(F > n_M)$. Others within this mode of production will equate market labor supply and demand $(F = n_M)$ or will hire more labor than supplied in the market $(F < n_M)$, as working capital endowments increase. These distinctions do not lead to unique modes of production by labor activities, but do provide a means of differentiating households in different "classes" of working capital endowments by comparison of the depth of their utilization of these activities.

If returns to teamwork are sufficiently large, the optimal solution to (2.6) will involve no household labor time on farm $(H = 0)$. All time not devoted to leisure is more profitably spent increasing the size of the team labor force either by working in the labor market to finance hired labor on farm (when $c_E > c_M + \frac{1}{T}c_F$) or by participating in labor exchange (when $c_E < c_M + \frac{1}{T}c_F$). These cases represent the four modes of production described in the last two rows of Table 2.1.

This typology indicates the endowment sensitivity of labor exchange. Under returns to teamwork, labor exchange may arise for farmers at various levels of land endowments in the first three market labor regimes depending on relative labor activity transactions costs. Labor exchange can be entirely ruled out only for farmers in the fourth market labor regime, those with the largest farms. These farmers can afford to hire the labor needed to optimally exploit returns to teamwork. They devote all of their labor time to supervision of this hired labor force.

These results demonstrate that, in the presence of returns to teamwork, the tidy classification of modes of production by working capital or land endowments alone no longer applies. The team production technology and the cost of labor transactions also affect which mode of production is observed. Moreover, returns to teamwork make labor exchange a viable labor arrangement for farmers across much of the distribution of working capital endowments. Interestingly, although the farmer's land endowment does not uniquely determine whether she participates in labor exchange through the endogenous selection of the mode of production, it affects her access to labor exchange through the village distribution of land endowments. Because transactions costs for labor exchange, c_E, rise in teams of farmers with heterogeneous farm size, a farm's location within the farm size distribution of potential exchange labor teammates affects whether labor exchange is part of that farmer's mode of production.

2.4 Market Imperfections, Endowments and the Demand for Labor Exchange

The typology just developed indicates the conditions on technology, markets and endowments in which labor exchange can arise. For various modes of production within this typology, I now consider how credit and labor market failures and household endowments of land and labor affect the decision to participate in labor exchange and the level of demand for labor exchange.

The full effect of rationing in the capital market on the decision to use labor exchange can be assessed through comparative statics. When the working capital constraint is not binding $(\lambda = 0)$, holdings of working capital and land endowments have no effect on the optimal demand for labor exchange $\left(i.e., \frac{dn_E^*}{d\bar{B}} = \frac{dn_E^*}{d\bar{A}} = 0 \right)$. If the working capital constraint binds $(\lambda > 0)$, then savings, access to credit and land endowments shape the labor allocation decision.

Consider the effect of an exogenous increase in working capital, say, through improved credit access $(d\bar{B} > 0)$, on the demand for exchange labor by constrained households.[32] This effect depends on which mode of production is observed. I consider $\frac{dn_E^*}{d\bar{B}}$ for the three most prominent modes of production in which labor exchange is used: self-cultivators using labor exchange, small-capitalist-cultivators using labor exchange, and laborer-cultivators using labor exchange. These are the three modes of production involving labor exchange in the middle panel of Table 1, in which the farmer also supplies other labor on her own fields $(H > 0)$. These modes of production are far more common in practice than the three modes of production involving labor exchange in the bottom panel of Table 1, in which no other household labor is used on farm.[33]

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[32] Because credit and land owned enter the working capital constraint in the same linear fashion, the effect of an increase in land endowments on demand for labor exchange differs from these results only by a scalar.

[33] In the sample of Indonesian farmers from the 1998-99 PATANAS survey, only 6.8 percent of households using labor exchange by season supplied no other household labor on farm outside of their work with the labor exchange team.

First, consider self-cultivators using labor exchange ($F = 0, H > 0, n_M = 0, n_E > 0$). The comparative statics analysis in (A2) of Appendix A shows that the effect of an increase in credit access on demand for labor exchange is characterized by the sufficient conditions

(2.11.a) $$\frac{dn_E^*}{d\bar{B}} > 0 \text{ if } f_2 f_{13} - f_3 f_{12} \geq 0 \quad \text{and}$$

(2.11.b) $$\frac{dn_E^*}{d\bar{B}} < 0 \text{ if } f_2 f_{13} - f_3 f_{12} < \frac{f_{12} f_{23} - f_{13} f_{22}}{u''}.$$ [34]

The condition for $\frac{dn_E^*}{d\bar{B}} > 0$ in (2.11.a) is weaker than the one for $\frac{dn_E^*}{d\bar{B}} < 0$ in (2.11.b), but which condition is satisfied depends on the production and supervision technologies and on preferences. As a special case, if labor time and team size are separable from land $\left(\frac{\partial}{\partial A}\left(\frac{f_2}{f_3}\right) = 0\right)$, then $f_2 f_{13} - f_3 f_{12} = 0$ and $\frac{dn_E^*}{d\bar{B}} > 0$.[35] More generally, the conditions in (2.11.a) and (2.11.b) are related to the relative substitutability of labor time versus labor teams for land. Although no concise conditions comparable to (2.11) on the relative elasticity of substitution for these factors can be derived, considering these elasticities provides some intuition. The direct elasticity of substitution of labor time for land and of team size for land, respectively, are given by

[34] See (A2) in the Appendix for details.
[35] See Chambers (1988) on the properties of separable production functions.

(2.12.a) $$\sigma_{12}^{D} = \frac{f_1 f_2 \left(Af_1 + Tf_2\right)}{AT\left(-f_{11} f_2^2 + 2 f_1 f_2 f_{12} - f_{22} f_1^2\right)}, \text{ and}$$

(2.12.b) $$\sigma_{13}^{D} = \frac{f_1 f_3 \left(Af_1 + nf_3\right)}{An\left(-f_{11} f_3^2 + 2 f_1 f_3 f_{13} - f_{33} f_1^2\right)},$$

where $T = H + L$ represents labor time from any source.[36] At a given level of factor use, a change in technology that increases f_{12} lowers σ_{12}^{D} and reduces the chances of meeting the condition for $\frac{dn_E^*}{d\bar{B}} > 0$ in (2.11.a). The technologically-driven increase in f_{12} makes labor time a poorer substitute for land. As improved access to credit increases demand for land and labor, labor time increases in relative importance to team size as a source of labor because it is not as easily substituted for land as before the change. This leads to weaker demand for labor exchange which is only a source of team labor and reduces total labor time on farm. Similarly, a technologically-driven increase in f_{13} relaxes the condition on $\frac{dn_E^*}{d\bar{B}} > 0$ in (2.11.a), making it easier for an increase in credit access to lead to a rise in demand for labor exchange. Again, this effect can be understood through the effect of an increase in f_{13} on σ_{13}^{D}. The rise in f_{13} reduces the substitutability of team size for land. As greater access to credit increases demand for land, there must be a larger increase in team size relative to before the change in f_{13}. For self-cultivators using labor exchange, the increase in team size can only come from labor exchange.

[36] Chambers (1988).

Whether condition (2.11.a) or (2.11.b) holds empirically depends, in part, on the source of demand for team labor. For example, if returns to teamwork derive from an activity that requires speedy completion, such as transplanting rice seedlings in irrigated padi, team size is a better substitute for land than is labor time. Greater access to working capital will induce the use of more land and a shift of household labor time from labor exchange, for which this land more easily substitutes, toward on-farm cultivation. This lowers supervision costs, increasing the amount of labor time on-farm for each hour of household labor supplied anywhere. For a sufficiently large increase in $\overline{B}$, a self-cultivator using labor exchange may change modes of production and begin hiring labor as well. Initially, this shift will reduce demand for labor exchange because of the availability of new wage labor substitutes.

Now consider the effect of an increase in access to working capital on demand for exchange labor for the mode of production of small-capitalist-cultivators using labor exchange. Farmers operating under this mode of production employ market labor and participate in labor exchange, but do not supply labor in the market ($F = 0$, $H > 0$, $n_M > 0$, $n_E > 0$). Improved access to working capital for these farmers relaxes a constraint on hiring paid workers from the labor market either to increase labor time or to expand team size on farm. This effect should reduce demand for labor exchange as a source of team labor when paid labor alternatives exist. To illustrate this effect, first-order conditions (A1.d) and (A1.e) for n_M and n_E, respectively, imply

(2.13) $$\frac{f_2}{f_3} = \frac{(1+\lambda)w}{f_2(s'+c)},$$

where I assume search costs in labor exchange and paid labor are identical $(c_E = c_M = c)$, for simplicity. The household employs paid market labor and exchange labor until the marginal rate of technical substitution of labor time to team size equals their relative cost in terms of the shadow value of market labor time divided by the productivity cost of reduced household labor time on farm. Equation (2.13) indicates one of the effects of imperfect capital markets. A decrease in the shadow value of working capital, λ, lowers the marginal rate of technical substitution of work time to number of workers at the optimum. This implies higher n_M and lower n_E, since a decrease in team size through labor exchange increases labor time. This also demonstrates that exchange labor is an imperfect substitute for paid labor, effectively satisfying only the team labor portion of labor demand.

However, this substitution effect of paid labor for exchange labor is not the full effect of a relaxation of the working capital constraint on demand for exchange labor in this mode of production. Increased liquidity for working capital constrained farmers also leads to larger operated land area at the optimum and a general increase in demand for team labor. Some of this new demand for team labor may be met through labor exchange, although the relative intensity of exchange labor use may decline. Whether substitution toward paid labor dominates the expanded demand for team labor in the effect of additional working capital on demand for labor exchange depends, among other things, on the substitutability of labor time for team size and the relative size of search costs for paid labor and exchange labor. The comparative statics analysis in (A3) in Appendix A shows that, because of these competing effects, an increase in access to working capital has an ambiguous effect on demand for labor exchange for farmers who are small-capitalist-cultivators with labor exchange. Nonetheless, some additional insight can be gained by considering part of the problem. Under the assumption that leisure is fixed, a sufficient condition for $\frac{dn_E^*}{d\overline{B}} < 0$ is $s' + c > 1$, as shown in (A3) in Appendix A. Supervision and search costs comprise the entire marginal cost of exchange labor. However, they represent a fraction of paid labor costs, which also include a wage component. One effect of an increase in credit access is to reduce the shadow cost of the wage component of paid labor costs. The preceding result states that when, in addition, the incentive and transaction cost component is large, greater access to capital reduces demand for exchange labor as paid labor becomes relatively more affordable. This is the negative substitution effect of an increase in working capital on demand for labor exchange. In general, when leisure is not fixed, it is not possible to obtain simple sufficient conditions on the sign of $\frac{dn_E^*}{d\overline{B}}$ for this mode of production. The ambiguity of this effect, particularly for farmers using paid labor as well as labor exchange, suggests that the role of cash constraints in bolstering demand for exchange labor may be overstated in the literature.

Finally, consider $\frac{dn_E^*}{d\bar{B}}$ in the laborer-cultivator mode of production with labor exchange. Farmers operating under this mode of production use labor exchange and supply labor to the market, but do not hire paid labor ($F > 0, H > 0$, $n_M = 0$, $n_E > 0$). Section (A4) of Appendix A shows that the effect of increased access to working capital on demand for labor exchange for farmers in this mode of production is positive:

(2.14) $$\frac{dn_E^*}{d\bar{B}} = \frac{1}{|\Delta|}\frac{u''}{v}\left(\frac{w}{v}(1+c)(s'+c)C_{33} + \frac{w}{v}(1+c)C_{32} + (1+c)^2 C_{31}\right) > 0,$$

where C_{ij} is the (signed) cofactor for the *i*th row and *j*th column of the Hessian matrix of second derivatives of the production function. Farmers in this mode of production that obtain increased access to working capital use the additional liquidity to finance an increase in the scale of operation through land acquisition. This increases demand for labor on farm. The farmers respond by decreasing labor time supplied off-farm and devoting more time to own-cultivation. However, this increase in labor time on farm cannot meet the new demand for team labor under positive returns to teamwork. Therefore, demand for labor exchange rises.

Because the working capital constraint is linear in working capital and land endowments, equation (2.14) also implies that demand for labor exchange is increasing in land area owned for farmers in this mode of production. These farms are the smallest in the continuum of market labor regimes in Table 1. This result shows that at this low scale of operation, labor exchange will be part of the process of development, providing the sole source of team labor as greater access to working capital allows the farmer to expand his operated area.

Next, I demonstrate the effect of an increase in the household labor endowment, or household size, on demand for labor exchange, $\frac{dn_E^*}{d\bar{n}_H}$. For small-capitalist cultivators using labor exchange or laborer-cultivators using labor exchange, it is not possible to determine the sign of $\frac{dn_E^*}{d\bar{n}_H}$. However, for self-cultivators using labor exchange, the effect of an increase in household size on demand for labor exchange is given by

$$(2.15) \qquad \frac{dn_E^*}{d\bar{n}_H} = \frac{1}{|\Delta|}\left\{u''\left(T\left(s' + c_E\right)f_{22} - Tf_{23} + \left(s' + c_E\right)f_{23} - f_{33}\right) - \left(f_{22}f_{33} - f_{23}^2\right)\right\},$$

where Δ is the Hessian matrix for the Langrangean for this problem and is positive by the characteristics of the production and utility functions. See Section A5 in Appendix A for details. The term $u''\left(T\left(s' + c_E\right)f_{22} - Tf_{23}\right)$ is positive and represents the role of additional household members in raising demand for labor exchange by increasing the time endowment of the household. The remaining terms in (2.15) all have a negative effect on $\frac{dn_E^*}{d\bar{n}_H}$. This is the effect of the larger household in substituting for labor exchange as a source of team labor. If this substitution effect of larger household size exceeds the time endowment effect, then demand for labor exchange will decline as household size increases. Whether the substitution effect dominates is an empirical issue that will be tested in Chapter 4.

The effect of household size on demand for labor exchange for self-cultivators depends on whether the household is working capital constrained. If the household is working capital constrained, an increase in household size leads to additional labor resources to be applied to a farm of fixed size. The negative substitution effect of household size on demand for labor exchange teams may be relatively large in this setting. On the other hand, if the household is not working capital constrained it will adjust to the presence of additional labor resources by increasing operated land area at the optimum. This dampens the downward effect of household size on demand for labor exchange because some of the additional labor resources are used to create a more extensive operation, not only a more intensive one. For the other modes of production that involve hiring or selling labor in the market, demand for labor exchange should be independent of household size for households that are not working capital constrained. For constrained households, there are similar substitution and time endowment effects and the net effect is an empirical question. Overall, this implies that household size should have either no effect or an attenuated effect on labor exchange use for unconstrained households. If the substitution effect dominates, the effect of household size should be more negative for households that are constrained.

2.5 Conclusion

The model developed here generalizes the multiple market failure model of Eswaran and Kotwal (1986) to include coordination benefits from teamwork. This makes it possible to establish the relative importance of the two most prominent explanations for the presence of labor exchange teams in agriculture, returns to teamwork and imperfections in labor and credit markets. Returns to teamwork are a necessary condition for the presence of labor exchange teams. Moreover, labor exchange only satisfies demand for team labor; it leads to a net reduction in labor time on-farm because it draws more productive household workers off farm as a way to attract teams. The argument that farmers join labor exchange teams because they do not have the cash to hire market laborers is fleshed out here. This scenario can only arise for farmers that are already employing both market labor and labor exchange when supervision costs for external laborers are high. For farmers that are autarkic with respect the labor market but use some exchange labor, greater access to working capital increases demand for land and may *increase* demand for labor exchange, depending on the relative substitutability of labor time and team size for land. For farmers that also work as laborers in the paid labor market, greater liquidity unambiguously increases demand for labor exchange as a needed source of team labor as the operation expands. These results show that the effect of credit market imperfections on demand for labor exchange are more subtle than previously described in the literature on labor exchange. As credit markets develop and working capital becomes more available, labor exchange use will increase among the smallest farmers. Larger farmers that also employ paid labor may reduce their reliance on labor exchange, although this effect is not guaranteed and depends on the characteristics of the production and supervision technologies. If the process of development is characterized by a reduction in population density in rural areas, average farm sizes may grow. This makes it more likely that demand for labor exchange will decline.

In addition to explaining the determinants of labor exchange, the model developed here justifies more of the observed modes of production in agriculture and clarifies the role of employment itself in the organization of agriculture. I show that allowing for returns to teamwork in production explains the common practice in agriculture of simultaneously employing labor on farm and supplying labor off farm. Although other explanations for this practice exist, only returns to team size also explains the use of this practice through the institution of labor exchange. Where returns to teamwork and labor exchange exist, the number of possible modes of production characterized by the pattern of observed labor activities is much greater than in the model by Eswaran and Kotwal. The mode of production that is optimally chosen by the farmer becomes a function, not only of access to working capital, but also of production technology, labor transaction costs and the local distribution of land. This increases the ability of the model to explain observed patterns of labor use.

The returns to team production introduced here are very general. They are consistent with the coordination benefits that Alchian and Demsetz (1972) use as a rationale for all employment relationships. In their seminal paper, employment occurs in order to take advantage of these coordination benefits. The hierarchical employer-employee relationship arises in order to assign residual claimancy, as a method of overcoming the weak incentives in output-pooling team production. The employer then has an incentive to monitor the employees and reduce shirking. These incentives are strengthened further in labor-pooling exchange labor teams through reciprocity in the rotation of the role of employer and through dynamic incentives for all team members to monitor each other. In the model by Eswaran and Kotwal, additional credit is always used to obtain more land and increase the scale of operation. This implies that the reason for the employment relationship is so that agents endowed with more land can obtain labor services from those with less land, thereby establishing an equilibrium of returns to labor across farms. Eswaran and Kotwal reject the teamwork motivation for employment in agriculture as empirically irrelevant.[37] The model developed here explicitly returns Alchian and Demsetz' motivation of gains from teamwork to the labor relationship. I show that a rather different pattern of the organization of production arises that more fully explains observed modes of production.

[37] In Chapter 4, I provide estimates of return to teamwork in agriculture that refute this claim.

3 The Indonesian Survey Data and Preliminary Evidence on the Determinants of Labor Exchange

3.1 The Indonesian PATANAS Survey Data

The empirical investigation into the operation and determinants of agricultural labor exchange uses the 1998-99 round of an Indonesian agricultural household panel survey data set known by its Indonesian acronym, PATANAS.[38] I collaborated with a research team from the Indonesian Center for Agro-Socioeconomic Research (CASER) and the World Bank to collect the data in April and May of 1999. The household survey provides data on nearly 1500 households from 35 villages from six of Indonesia's 27 provinces: Lampung, West Nusa Tenggara, Central Java, East Java, North Sulawesi and South Sulawesi. This round of the PATANAS survey is well suited to this research. It provides detailed information on agricultural production, asset ownership, savings, and credit use. The on-farm labor demand module of the questionnaire captures labor hours by contract type (i.e., time wage, piece rate, labor exchange), by season and activity. Individual labor supply is available for all household members. This sample captures much of the diversity of agro-ecological zones in these provinces, and so should provide sufficient variation in crop mix and technology to inform how these factors affect the use of labor exchange. It should also contain considerable regional variation in the depth of factor markets. The two provinces on Java are very densely populated and are easily accessible from Jakarta, the capital and main commercial center of the country. The

[38] This Indonesian acronym stands for *Panel Petani Nasional*, which translates into National Farmer Panel Survey. This is a misnomer because the survey never included more than 8 of Indonesia's 27 provinces.

provinces in Sulawesi, on the other hand, are less densely populated and significantly more remote. There is also considerable variability from village to village within a province in terms of access to urban centers. This variability should help to identify the role of labor and credit market failures in the decision to use labor exchange.

The 1998-99 round of the PATANAS sample has the most comprehensive questionnaire of an annual household panel survey that covers 1994-99.[39] The survey includes village censuses in 1994 and 1998, and more limited surveys on selected topics in 1994-95, 1995-96, 1996-97. The 1994-95 survey included an agricultural production module, but with primary focus on a single plot and with less detail on labor demand than the 1998-99 round. The other survey rounds provide some evidence on the prevalence of labor exchange, but do not enable a full accounting of the source of exchange labor demand. Therefore, I take advantage of the earlier survey rounds to investigate patterns of prevalence of labor exchange, but I only use data from these rounds in estimation as a source of some retrospective variables.

The sample design was a purposive sample within these six provinces, intended to cover much of the substantial diversity of agro-ecological conditions in Indonesia. The sampling approach involved a two-stage clustered random sample with two levels of stratification. First, each province was stratified into up to five agro-ecological zones characterized by elevation above sea level and length of the rainy season. Villages were then selected from within the agro-ecological zones to capture the key crops,

[39] CASER first conducted an annual agricultural household survey under the acronym PATANAS from 1984-88. This survey used a different sampling frame from the PATANAS surveys of the 1990s.

topographies and cropping patterns, in number proportional to the size of the zone. Within each village, a "block census" was conducted in 1994 over a sub-region of the village because funding and time constraints precluded a complete village census. Villages in Indonesia consist of a series of *kampung* or sub-regions differentiated by physical borders such as a river or road. In the first stage, data were collected on each *kampung* concerning primary sources of economic activity, crops grown, and topographical characteristics. CASER researchers then identified an area (or "block") made up of one or more *kampung* that would provide a census population of close to 200 households per village. These blocks served as the sample clusters. The *kampung* chosen for the census were those considered to be qualitatively representative of the village population based on commodities grown and share of households with livelihoods based in agriculture. A benefit of this clustered sample for socio-economic research is that the households surveyed in each village are likely to have common institutional arrangements in land, labor and credit markets due to their proximity. The 1994 census provided basic information on socio-economic, demographic and farm characteristics for 6585 households in 35 villages in the 6 provinces. Within each cluster, a random sample of approximately 50 households was chosen for the first survey round in October 1995 from the roughly 200 census households per village, yielding a sample of 1758 households. The sample of households selected from the census was stratified by landholdings (of 0 ha., 0-0.25 ha., 0.25-0.49 ha., 0.5-1.0 ha., and >1.0 ha.) and farming status (primary income source from agriculture or outside agriculture).[40] Although the sample does not constitute a "representative sample" of rural Indonesia, or of the rural

[40] An Indonesian-language summary of the PATANAS sample design is provided in Soentoro et al (1994).

areas of the six provinces, it provides a detailed picture of the major agricultural activities in these provinces.

Of the original 1758 households in the 1994-95 sample, 1588 were re-interviewed in 1999 (an attrition rate of only 9.7 percent in four years). Enumerators were mostly CASER researchers with extensive experience in data collection and in research on production and socio-economic activities of farm households. All enumerators resided in the study villages during the enumeration in 1999. In addition to assisting in the design of the questionnaire, particularly the labor modules, I accompanied the research team for the pre-test of the survey instrument. During the enumeration, I visited several of the enumeration teams in Central Java, West Nusa Tenggara, and South Sulawesi. Once the data were available electronically, they were carefully checked for errors. After removing observations because of data inconsistencies, the final 1998-99 data set includes 1494 households (an effective attrition rate of 15 percent). Each of the 35 villages had between 28 and 49 households interviewed, with an average of 43 households per village. Table B.1 in Appendix B lists the name of each village, its district or *kabupaten*, and the main crops grown, by province. Table B.2 provides the number of household observations per village for the 1999 sample.

At the same time that the household survey was being conducted, two Indonesian sociologists visited a number of the 1998-99 PATANAS sample villages and some neighboring villages. Their main objective was to investigate the effects of the 1997-98

Indonesian financial crisis on the households in these villages.[41] Through focus group discussions and interviews with key informants, the sociologists collected information on land tenure arrangements, borrowing and lending behavior, rural household attitudes toward asset management and risk, inter- and intra-household relationships, incidence of illicit activities, formal and informal institutional arrangements, communal activities, and maintenance/upgrading of village infrastructure and social services. These qualitative data provide some useful background information on labor arrangements and on the completeness of rural labor markets.

3.2 The Prevalence and Operation of Labor Exchange Teams

Labor exchange is common in Indonesia. In the 1998-99 PATANAS sample, labor exchange teams were found in 23 of the 35 villages. The names of these villages are listed in bold font in Appendix Table B.1. I will refer to these as "labor exchange villages," a classification which requires some justification. Most of the same villages had evidence of labor exchange in the 1994-95 round of the PATANAS survey and in the 1998 village census. Using data on the primary plot for the 1994-95 sample—the only plot for which labor contract type was reported—26 of the 35 villages had the same labor exchange classification in both 1994-95 and 1998-99. Of the remaining villages, only two had some labor exchange in 1994-95 and not in 1998-99. In the seven villages with evidence of labor exchange in 1998-99 and not in 1994-95, it is not known whether labor

[41] The World Bank used the PATANAS panel survey to study the effects of the 1997-98 financial crisis on rural households. See Gilligan et al (2000) and Bresciani et al (2002).

exchange was used on secondary plots in the first round. The 1998 village census also provides considerable support for a classification of labor exchange villages based on the 1998-99 sample, but the census data are less complete. The 1998 census was not conducted in the province of East Java due to social unrest there, and in the other provinces nearly eight percent of households from the 1995-1999 panel were missing in the census.[42] Moreover, complete production data were not collected in the 1998 census. Only a checklist was used to indicate use of external labor by contract type and activity, so I expect these data to be less reliable. With these caveats in mind, the most significant inconsistency for the village labor exchange classification between the 1998-99 sample and the 1998 village census is that one village in South Sulawesi, Polo Padang, had extensive use of labor exchange in 1998, but no labor exchange in the 1998-99 sample. However, of the seven villages not in East Java with no labor exchange in 1994-95 or 1998-99, only two villages had evidence of labor exchange in the 1998 census, and one of those involved only 2 households. Finally, the 1996-97 PATANAS sample offers more support. Respondents to the survey were asked how the prevalence of labor exchange had changed in the past decade, which provides indirect evidence of its presence in the village.[43] As with the 1998 census, these data are less reliable because of their qualitative nature; they likely under-represent labor exchange prevalence. Still, responses in the 1996-97 survey indicate that labor exchange was being used in 17 of the 23 villages with labor exchange in 1998-99. Of the 12 villages with no labor exchange in 1999, only one had evidence of labor exchange in 1996-97.

[42] I do not know why these households were omitted from the census. The incompleteness of the 1998 census does not seriously affect the sampling properties of the 1998-99 sample, which is based on the panel started with the 1994-95 sample and the census conducted in 1994.

This overview of village-level prevalence of labor exchange in the PATANAS surveys shows no use of labor exchange in eight of the 35 villages over a four-year period. This suggests that the institution of labor exchange does not exist everywhere. There may be fixed costs arising from the need to agree on rules of operation as well as learning effects that keep labor exchange from operating at all in some areas. Therefore, I treat those villages without labor exchange in the 1998-99 sample as lacking the labor exchange institution. Although early survey rounds indicate that a few of these villages may have had labor exchange in the recent past, the 1998-99 survey data are the most reliable so I use them to classify villages into those with and without labor exchange. Farms in these "labor exchange villages" form the sample for the empirical investigation of the household decision to use labor exchange in the next chapter. It is possible that a few of those villages omitted from the sample should have been classified as labor exchange villages, but no farmer in the 1998-99 chose to use labor exchange in that year. If so, the most serious implication for the estimation in Chapter 4 is probably a loss in efficiency.

Table 3.1 lists the proportion of households primarily engaged in farming that used labor exchange in 1998-99 by village. This farming sample includes 1209 households, of which 884 live in labor exchange villages. In all, 201 of these households used labor exchange at least once in 1998-99. This represents 16.6 percent of the entire farming sample and 22.7 percent of farming households in labor exchange villages. The villages in which the labor exchange institution was operating in 1998-99 are geographically

[43] Counting only unique responses by households across activities, 71 percent said the prevalence of labor exchange had not changed, 22 percent said it was becoming more rare, and 6 percent said it was becoming

dispersed. There are sample villages in all six provinces that have labor exchange, although the arrangement is not common in the sample from East Java.

Table 3.1: Share of Farming Households Using Labor Exchange by Village, 1998-99 (%)

Province	**Village, by ID Number** 1	2	3	4	5	6	7	Province Average
Lampung	7.1	14.3	27.9	8.5	18.4	2.4		13.0
Central Java	26.2	17.2	50.0	13.9	0.0	0.0	5.9	19.8
East Java	5.3	2.6	0.0	0.0	0.0	3.2		3.0
West Nusa Tenggara	0.0	7.3	7.1	21.7	47.8			19.0
North Sulawesi	0.0	32.6	0.0	0.0	8.8			9.8
South Sulawesi	0.0	32.5		78.6	0.0	56.1	0.0	27.7
TOTAL								16.6

Labor exchange is a significant source of labor for those households that use it. On average, labor exchange constitutes 47.9 percent of all non-household labor hours on farm for households using labor exchange, with an interquartile range of 21.6 - 75.0 percent. Of these households, 16.9 percent use no other source of outside labor. As a share of total on-farm labor demand, labor exchange constitutes an average of 14.8 percent of labor hours by all sources for farms using labor exchange, with an interquartile range of 4.0 – 18.4 percent.

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more common.

Sociologists studying labor exchange generally indicate that a farmer's reliance on labor exchange fluctuates over time in response to changes in economic conditions and the time demands of team members (e.g., Erasmus, 1956; Geschiere, 1995). Indeed, in his extensive studies of labor exchange in South American and the Caribbean, Erasmus only found one example of the use of permanent or semi-permanent exchange labor teams, in Haiti. Evidence from the PATANAS sample supports this view, as farmers show considerable variability in their use of labor exchange. Despite considerable stability in the presence of labor exchange as an institution in a village, farmers in labor exchange villages move in and out of labor exchange for subsequent activities within seasons, across seasons within a year, and from year to year. The 1998-99 PATANAS survey records labor use by plot and season for farming activities grouped into six categories: land preparation, plowing, planting, weeding, harvesting, and milling/transport. For each season in which a farmer used labor exchange for at least one farming activity in 1998-99, 35 percent participate in labor exchange again for subsequent activities in the same season. Table 3.2 presents the distribution of the labor contracts by type across seasons in 1998-99.[44] The PATANAS survey includes hours of labor demand under labor exchange and by four types of paid market labor: daily wage, piece rate, output share and tied contracts.[45] The survey also recognizes whether it was a team that performed work under each of these paid labor contracts, but the size of the team is not known.[46] Of the

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[44] The timing of the seasons during the year varies by region, but roughly corresponds to the following months on the calendar: dry season I, April–June 1998; dry season II, July–September 1998; rainy season, October 1998–March 1999.

[45] Under tied contracts, the worker supplies labor for multiple activities during the cropping season (e.g., planting, weeding, harvesting) and agrees to wait for payment for all activities until after the harvest (see Mukherjee and Ray (1995) and Caselli (1997)).

[46] In many cases, production data were aggregated across plots during enumeration when multiple plots were homogenous with respect to crops grown and farming technique. This aggregation reduces the total

826 labor exchange contracts recorded in 1998-99, 58.2 percent took place during the rainy season. Of the 204 households in the full sample that used labor exchange in at least one season, 35.8 percent used labor exchange again in another season that year. Only one third of the households using labor exchange in 1998-99 reported using it on their main plot in 1994-95. These results understate labor exchange use in 1994-95 because information on labor contract type is only available for the main plot for that year. However, 109 other households reported using labor exchange on their main plot in 1994-95, but did not use it in 1998-99. These patterns indicate that farmers do not make rigid commitments with labor exchange teammates from year to year or across seasons. Estimates of determinants of labor exchange participation in the next chapter will provide evidence of the economic motivations for this observed flexibility in labor exchange participation.

As described in Chapter 1, the two primary forms of agricultural labor exchange are what Erasmus (1956) termed "exchange labor" and "festive labor". The former involves immediate reciprocity in labor time and, typically, payments, if any, are limited to meals. In the latter, the timing of labor reciprocity is usually unspecified, so side payments are larger to compensate for delayed and less certain reciprocity. The PATANAS questionnaire does not specify which form of labor exchange is operating. The Bahasa Indonesia terms used for exchange labor in the survey instrument are *sambatan* or *arisan kerja*. Both terms can be applied to either form of reciprocal labor exchange.[47] In order

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number of labor contracts in the data, although contract-level observations are still unique by activity and form of payment.

[47] The Indonesian word *sambatan* is also used for a third kind of labor exchange, commonly referred to as *gotong royong*, in which neighbors pool their labor for public good provision such as constructing roads

to avoid confusion in the following discussion, I will refer to the former type of labor exchange as “rotating exchange labor” and the latter as “festive labor”, since festive labor does not always include a complete rotation of team members as host.

Table 3.2: Distribution of Labor Contracts across Seasons by Type of Contract, 1998-99

	Number of Contracts				
Type of contract	**Seasonal Crops**			**Annual Crops**	**Total**
	Rainy Season	Dry Season II	Dry Season I		
	Oct ’98 – Mar ’99	Jul ’98 – Sep ’98	Apr ’98 – Jun ’98	Apr ’98 – Mar ’99	
Daily wage	2546	1437	1896	752	6631
Piece rate	851	342	578	268	2039
Output share	391	51	165	21	628
Tied	45	15	37	0	97
Labor exchange	481	83	224	38	826
Daily team	7	1	0	0	8
Piece team	103	83	82	105	373
Share team	198	2	64	6	270
Tied team	3	0	3	1	7
Other	46	7	22	21	96
Total	4671	2021	3071	1212	10975

A review of secondary sources and inspection of payments made under labor exchange in the PATANAS sample suggest that rotating exchange labor is the more common form of reciprocal labor exchange team in the data. Goethals (1967) describes the operation of labor exchange teams in Rarak village in West Sumbawa, which is in one of the districts in West Nusa Tenggara represented in the PATANAS sample. According to Goethals, rotating exchange labor and two forms of festive labor are used in Rarak, but the former,

and public buildings. The word *arisan* refers to a scheme for periodic contributions from a group with a rotating schedule of rewards. When used alone, the word *arisan* most commonly refers to rotating savings known there as *basiru*, is more common and is used for more tasks. Utomo and Chotim (2000), the sociologists that accompanied the 1998-99 PATANAS fieldwork, confirm the use of *basiru* rotating exchange labor teams in some of the sample villages in Lombok, West Nusa Tenggara. However, in contrast to the description of *basiru* given by Goethals, Utomo and Chotim indicate that *basiru* team members sometimes received harvest shares when the *basiru* rotating exchange labor teams were employed for harvesting activities. This suggests some flexibility in the structure of the organization of labor exchange arrangements and that it is not always possible to strictly classify teams according to the characteristics of rotating exchange labor or festive labor. Utomo and Chotim also identify the use of conventional rotating exchange labor (without payments) in sample villages in Central Java, but in Pakuweru village in North Sulawesi a form of festive labor is used.

The pattern of cash or in-kind payments made through labor exchange generally supports the hypothesis that rotating exchange labor is more common than festive labor in the sample. In the 1998-99 sample, 82.2 percent of the 826 labor exchange teams employed by farmers received some form of payment. However, only 11.2 percent of labor exchanges included cash payments, and 72.1 percent included payments in kind. Presumably, most of these in-kind payments were in the form of meals, although some may have been harvest shares as indicated by Utomo and Chotim. If these teams are exchange labor, payments should be relatively small compared to local wage rates and payments equivalent to those observed should be returned to the farmers in the sample as they complete the rotation of work on teammates' farms. If the teams are festive labor,

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and credit associations (ROSCAs). The word *kerja* means work.

payments should be larger, but the labor time supplied on teammates farms and corresponding payment may not be observed in the twelve months covered by the survey. The data on labor supplied off farm by household members under labor exchange is less complete than the data on on-farm labor demand through labor exchange, so it is not possible to confirm reliably for farmers hiring labor exchange that reciprocal payments were received or that labor received was reciprocated.

Table 3.3 shows median hourly pay by type of labor contract by province for all external labor used on farm in the 1998-99 sample. The validity of these data is supported by the fact that higher incentive piece rate and output share contracts have higher median pay than low incentive time rate contracts. In Lampung, East Java, and West Nusa Tenggara, median pay through labor exchange is about half the value of the wage rate. This is consistent with an interpretation of these payments as the value of a mid-day meal for a work team providing hard physical labor under rotating exchange labor. Table 3.4 shows the average share of labor payments made in-kind by type of labor contract. Time rate contracts pay roughly one quarter of the wage in kind. In time rate contracts, these in-kind payments are mostly meals. However, since not all time rate contracts supply meals, this figure is a lower bound on the share of meals in time rate payments. Therefore, largely in-kind payments of half the wage rate seems to suggest that the teams operating in Lampung, East Java, and West Nusa Tenggara are mostly rotating exchange labor teams. In South Sulawesi, payments in labor exchange are roughly one quarter of the wage rate and in North Sulawesi, the median labor exchange team received no payment. Median wage rates are also higher in these two provinces. These results are consistent with the general abundance of land and smaller supply of market farm labor in these areas. Again, these figures suggest that rotating exchange labor is more common than festive labor in the sample villages in these two provinces. The exceptional case in Table 3.3 is Central Java, where median pay received under labor exchange is equal to the median wage rate. This suggests that some of the labor exchange contracts observed in Central Java may in fact be festive labor arrangements.

Table 3.3: Median Hourly Pay by Type of Labor Contract by Province, 1998-99 (Rp. '000)*

	Province					
Labor Contract	Lampung	Central Java	East Java	West Nusa Tenggara	North Sulawesi	South Sulawesi
Daily wage	1.1	1.1	1.1	1.2	1.8	1.7
Piece rate	1.4	1.3	1.9	1.8	2.1	2.0
Output share	3.4	3.4	2.4	2.2	2.6	2.4
Labor exchange	0.43	1.1	0.50	0.63	0.0	0.4

* Payments across activities in tied labor contracts cannot be linked in the data, so these contracts are omitted. The exchange rate in Q1 1999 was Rp. 8,776/$US (IMF, International Financial Statistics database).

If a fraction of the labor exchange teams observed in the sample are festive labor rather than exchange labor, this does not have serious consequences for this research. The most important implication is that festive labor is less effective at overcoming cash constraints for the host farmer, since the party that accompanies festive labor is typically very costly and these costs are not recovered immediately through reciprocity. In addition, the effort incentives are weaker in festive labor because of the delay in reciprocity.

Although the predominance of the evidence supports the hypothesis that most of the labor exchange teams in the PATANAS sample are of the rotating exchange labor type, the frequency and magnitude of payments made through the labor exchange in the Indonesian data indicates that these arrangements transfer meaningful amounts of resources other than time.

Table 3.4: Share of Labor Payment Made In-Kind by Type of Labor Contract, 1998-99

Type of Contract	*Number of Contracts*	Mean Share of Payment In Kind (%)	Std. Dev.
Daily wage	6616	27.2	22.0
Piece rate	1961	1.3	10.4
Output share	619	98.6	10.5
Tied	82	88.5	31.4
Labor exchange	680	86.9	33.3

The PATANAS data provide other evidence on the operation of labor exchange teams concerning such issues as interlinked exchanges and team composition. In describing labor exchanges in Rarak village in West Nusa Tenggara, Goethals (1967) states that labor exchanges are sometimes arranged as a mechanism for sharing farm equipment such as draft animals or plows. These interlinked arrangements are rare in the PATANAS sample. Only 6.9 percent of labor exchange teams were employed in plowing activities that involved animal traction or use of a tractor, and nearly all of these were in North and South Sulawesi.

The prevalence of female workers in labor exchange is similar to other labor arrangements. In all labor exchange teams hired on farm by households in the 1998-99 sample (excluding those interlinked with farm equipment), 61.8 percent were all male, 31.6 percent were all female and 6.6 percent used males and females. This compares to 63.6 percent men, 33.0 percent women, and 3.4 percent mixed gender teams in all (non-equipment) external labor used on farm. However, labor exchange teams are somewhat more likely to be homogenous than work teams hired under other types of labor contracts. The number of labor contracts, other than those interlinked with farm equipment, that involve work teams are primarily in labor exchange (N=754), piece rates (N=369), and output share contracts (N=270). The fraction of these teams that included both genders was 6.6 percent, 6.8 percent and 38.5 percent, respectively. Although labor exchange teams are just as likely as piece rate teams to be mixed-gender, they are far less likely to do so than teams paid by output shares. Even if exchange labor contracts are restricted to those involved in harvesting work, as are all output share contracts, the fraction of teams that are heterogeneous rises only to 11.5 percent. This evidence provides some support for the hypothesis that the membership of labor exchange teams tends to be homogenous as a means of equalizing productivity or fostering trust in these reciprocal exchanges. However, it is not clear why piece rate teams are similarly homogenous, but output share teams much less so. This pattern would be consistent with the hypothesis that teams pooling rewards select equally productive members if piece rate teams divide their compensation equally but output share teams pay members according to how much each one harvested. Unfortunately, I do not have sufficient information about the operation of these other team arrangements to confirm this claim.

3.3 Preliminary Evidence on Determinants of Labor Exchange: Qualitative Evidence from Direct Elicitation

The most direct evidence on farmers' reasons for participating in agricultural labor exchange is provided in the 1996-97 round of the PATANAS survey, which focused on land titling and agricultural labor relations.[48] Farmers who participated in agricultural labor exchange were asked to provide the reason for their participation in each activity for which they used exchange labor by season. The reasons coded in the questionnaire are unfortunately rather incomplete, but include (i) does not require cash, (ii) wages are high, (iii) labor supply is limited, and (iv) local custom. The frequency of responses is listed in the first two columns of Table 3.5. These responses were given by 183 farmers for various activities by season. Because a farmer might be expected to repeat the same response for different activities, I consider the number of unique responses by each farmer. Only 15 farmers varied their response to the question over activities. The distribution of these 198 unique responses over the four reasons is similar to that for all responses as shown in the last two columns of Table 3.5.

[48] The 1996-97 survey did not gather production data. The section of the survey instrument that focused on agricultural labor relations identifies which type of labor contracts were used and the reasons for their use. Because these data were not collected in the context of a broader set of questions on factor demand, they are not as reliable an indicator of individual household use of labor exchange as are the data from 1994/95 and 1998/99. The 1996/97 survey does indicate reasons for using labor exchange, although possibly with uneven coverage of the sample.

Table 3.5: Reasons for Participating in Labor Exchange, 1996-97

	All Responses		Unique Responses	
Reason	Freq.	Percent	Freq.	Percent
Does not require cash	120	23.4	44	22.2
Wages are high	13	2.5	5	2.5
Labor supply is limited	25	4.9	13	6.6
Local custom	355	69.2	136	68.7
Total	513	100.0	198	100.0

Using the unique responses, 22.2 percent of the farmers in Table 3.5 indicate that constraints on liquidity induce them to participate in labor exchange. Another 6.6 percent of labor exchange participants claim to use it because labor market imperfections make it hard to find workers. Less than 3 percent of responses state that they use labor exchange to avoid paying high wage rates in the market. This could represent another source of labor market imperfections, or it could be that these farmers are simply at a corner solution on their labor demand curves at wage rates that clear the market. Surprisingly, when given a choice to identify capital market failures, labor market failures or local custom as the primary reason for using exchange labor, nearly 70 percent of households claimed that it is customary practice that led them to use labor exchange. This suggests that factor market failures are not the primary source of demand for labor exchange in these data, although they are a significant reason identified by farmers. To some extent, the coded response “local custom” is a residual category that respondents may have chosen if the need for speedy task completion or some other source of returns to teamwork was their main reason for using labor exchange. However, with so many farmers choosing this response, the social obligations and rewards that come with maintaining this customary practice must be an important influence on the decision to use labor exchange.

A better understanding of the role of factor market failures is obtained by considering how responses differ by activity. The first panel of Table 3.6 shows the frequency of reasons for using labor exchange by six activities: plowing, planting, weeding, harvesting, transport, and milling. The share of farmers that use labor exchange for plowing and planting activities because it does not require cash is around 20 percent in each case, similar to this share for all activities. However, 40 percent of farmers using labor exchange for weeding claim that cash constraints are the reason. This provides some validation of farmers' responses to this question, since we expect cash holdings to be lowest for activities just before the harvest. For harvest activities, only 18 percent of responses are for cash constraints, the lowest share choosing this response for any activity.

The second panel of Table 3.6 shows the distribution of responses by province. Cash constraints are far more important in West Nusa Tenggara (at 36.2% of responses) than in any other province except for neighboring East Java, which has far fewer farmers using labor exchange. Tight labor markets are mentioned as a reason for using labor exchange only in Central Java and South Sulawesi, representing roughly 7 percent of responses in both provinces. This is interesting because these two provinces appear to have very different labor markets. Central Java is densely populated, is close to the national capital and commercial center, Jakarta, and has an active labor market. Rural Central Java is often characterized as a classical surplus labor setting. Reports of labor shortages there suggest that workers may be drawn to income-earning opportunities outside agriculture. In South Sulawesi, which is much less densely populated and has relatively abundant land, tight agricultural labor markets might arise seasonally because of a small agricultural labor force.

Table 3.6: Reasons for Participating in Labor Exchange by Activity and by Province, 1996-97

	Reasons				
	Does not require cash	Wages Are High	Labor supply is limited	Local custom	Total
By Activity					
Plowing	21	1	2	65	89
Planting	36	3	6	128	173
Weeding	24	2	2	32	60
Harvesting	20	4	5	81	110
Transport	16	3	10	45	74
Milling	3	0	0	4	7
By Province					
Lampung	12	0	0	37	49
Central Java	60	12	18	161	251
East Java	5	1	0	2	8
West Nusa Tenggara	38	0	0	67	105
North Sulawesi	2	0	0	0	2
South Sulawesi	3	0	7	88	98
Total	120	13	25	355	513

Other subjective responses on the benefits of teamwork in general were given elsewhere in the 1996-97 household survey. Respondents that worked as laborers were asked if they worked as part of a team. Those who indicated working in a team were asked why.

The 90 respondents that worked as part of a team indicated their reasons for doing so in the following categories: income is higher (13.3%); difficult to find work individually (15.6%); work must be done in a short time period (53.3%); work is joint with machinery (7.8%); and other (10.0%). Higher incomes under teamwork suggest the presence of a productivity advantage to team labor among those that responded. However, the most common response was that the task needed to be completed quickly. This provides further evidence of a technologically driven demand for teamwork for farmers in this sample. As shown in Chapter 2, this is a necessary pre-condition for the use of labor exchange. If this source of labor demand is common on farms in these areas, labor exchange could serve as a viable source of labor supply.

Another piece of evidence on the sources of demand for labor exchange teams, in particular, is provided by the PATANAS sociologists' interviews with local farmers during the 1998-99 PATANAS survey round. They indicate that a steep rise in wage rates following periods of intense out-migration in Lombok (West Nusa Tanggara) and Menado (North Sulawesi) led to the revival of labor exchange activities in these areas (Utomo and Chotim, 2000). This testimony counters to some extent the evidence just presented from respondents in the 1996-97 survey, and supports an association between conditions in the labor market and demand for this non-market labor institution.

3.4 Preliminary Evidence on Determinants of Labor Exchange: A Quantitative Summary of Household and Village Characteristics

Before proceeding with a review of the evidence on determinants of labor exchange from the PATANAS data, it is important to recognize that some of the vital determinants of the presence of labor exchange in a village, and of its use by a household, may have long histories that cannot be captured in cross-sectional data or even in a five-year panel. For example, the successful operation of labor exchange teams relies on the strength of local norms of reciprocity that have developed over many years. In addition, there may be important information and organizational impediments to the initial introduction of the labor exchange institution in a village that present the greatest barriers to its use. It may be that overcoming these impediments to the introduction of labor exchange is a kind of public good, forever making it less costly for future groups of farmers to adopt the labor scheme because the institutional framework has been established. Moreover, many of the current manifestations of general economic conditions affecting labor exchange use, such as the local distribution of land and land tenancy arrangements, the reliance on cash in the local economy, and the presence of supporting local infrastructure, have evolved over a long period. In some cases, it is the evolution of these factors more than their status at any given point in time that will determine the structure of labor exchange and its prevalence. These dynamic economic issues cannot be captured with the data available here; indeed, they are difficult to capture in most settings. However, keeping these issues in mind will assist in providing a more careful interpretation of current economic conditions as potential determinants of labor exchange.

I now investigate village and farm characteristics in the PATANAS data to obtain more evidence about the importance of team production and credit and labor market imperfections as possible determinants of labor exchange. The data also identify sources of labor transaction costs that help to determine which mode of production from the model in Chapter 2 is observed. Although the associations presented in this section do not provide conclusive evidence of the determinants of labor exchange, they will establish the context for a more rigorous empirical investigation in the next chapter.

An examination of village characteristics provides mixed support for the hypothesis that the institution of labor exchange arises primarily in villages with high transaction costs in the labor market and rationing in the credit market. Table 3.7 compares means and standard deviations of village-level variables derived from the sample of households primarily engaged in farming for the 23 villages with labor exchange and 10 of the other villages.[49] Labor exchange villages have larger farms and are more remote on average than other villages, although the difference in means is not significant for either of these variables, which may be due in part to the small number of villages.[50] If true in a larger sample of villages, these differences would be consistent with thinner labor markets in villages with labor exchange. However, labor exchange villages have a larger share of adults working as agricultural laborers, suggesting the local labor force may be no smaller than in non-labor exchange villages.

[49] Two of the 12 villages without the labor exchange institution are not included in Table 3.7 because they had few households whose primary activity is farming.

[50] The t-test for equality of means of each variable across the labor exchange and non-labor-exchange villages is based on the assumption of homogenous variance across the two distributions. If this assumption is violated, these hypothesis tests are invalid. This is the well-known Behrens -Fisher problem. Given the mostly exploratory objective of these comparisons, I do not attempt to verify the assumption of homogenous variance.

With regard to credit markets and constraints on working capital, credit use is substantially higher in villages with labor exchange. Households in labor exchange villages are more likely to use credit to finance production and investments and they have larger loans outstanding, although this difference is only weakly significant (p-value of .114). Perhaps because of the availability of credit, households in labor exchange villages have lower savings than in other villages. Nonetheless, they have larger holdings of other assets. Households in these villages also sell significantly more of their crop on average than elsewhere, which suggests that cash constraints may not be associated with the labor exchange institution.

The variability in plot size is generally lower in labor exchange villages, as measured by the logarithm of the absolute deviation of observed plots from village mean plot size. This suggests that heterogeneity in plot area may conflict with the reciprocal exchange of labor time under labor exchange teams. However, the average share of plots within ten percent of the area of the observed plot is significantly higher in villages without labor exchange. This measure is more specific concerning the availability of potential labor exchange teammates if homogenous plot size is an important constraint to labor exchange. It suggests that plot area homogeneity is not associated with the presence of the labor exchange institution in the village.

The presence of labor exchange also appears to be correlated with a general lack of technical progress, including lower use of high-tech irrigation equipment and slower adoption of high-yielding variety seeds, although the latter difference is not significant. Most labor exchange teams in the data operate on plots where rice or corn is grown. This could indicate relatively large returns to teamwork in the production of these crops, although it is also consistent with a need for homogeneity of crops grown within a labor exchange team. In the Indonesian data, the presence of labor exchange in the village is not associated with rice cropping intensity. The share of cultivated area planted in rice is 38.9 percent in villages without labor exchange and 24.7 percent in villages with labor exchange, although this difference is not significant. This argues against relatively greater returns to teamwork for production of rice than for other crops. The share of area planted in corn is somewhat higher in labor exchange villages (11.9 percent) than in non-labor exchange villages (6.3 percent). Although rice cropping intensity is lower in labor exchange villages, rice and corn are among the most common crops in many of the villages so that farmers of these crops may be more likely than others to find labor exchange teammates if crop homogeneity is required.

Another statistically significant difference between labor exchange villages and the other villages in the sample is average years of education of the household head. Household heads in labor exchange villages average only 4.7 years of education to 5.7 years for their counterparts in the other villages. This suggests that education is negatively associated with the development or maintenance of this cooperative non-market labor institution. It may be that education provides other opportunities for farmers outside of agriculture or increases their access to markets, so that reliance on labor exchange is not necessary. An alternative explanation is that education teaches individuals to be wary of others' motives, reducing trust and the desire to engage in reciprocal exchange relationships.

Table 3.8 presents characteristics of the households from the farming sample that live in labor exchange villages by labor exchange use.[51] Mean area planted was significantly higher for households involved in labor exchange. This could indicate that larger plot sizes are required for returns to team size to take hold. However, it may also support an argument based on labor market search costs if the correct interpretation of these data is that labor exchange is more common in villages with larger farms that have an abundance of land and smaller labor markets.

[51] Table 3.8 presents sample means only for households from the farming sample that had complete data for all variables listed. In this sample with complete data, 32.4 percent of households in labor exchange villages joined labor exchange teams in 1998-99.

Table 3.7: **Comparison of Means Across Villages With and Without Labor Exchange, 1998-99**

Variable	Labor Exchange Villages (N=23)		Non-Labor Exchange Villages (N=10)		
	Mean	S.D.	Mean	S.D.	
Area planted, Ha	1.598	0.782	1.350	0.818	
Ln avg. absolute deviation from village mean plot size	-1.420	0.769	-1.922	0.956	
Share of planted area owned by household	0.804	0.115	0.835	0.134	
Share of village plots within 10% of plot's area, avg.	0.114	0.046	0.192	0.109	***
Household size	4.635	0.602	4.681	0.443	
Median distance to market	2.173	3.680	1.700	1.855	
Share of adults working as agricultural laborer	0.184	0.128	0.161	0.152	
Number of plantings	1.668	0.483	1.939	0.554	
Share of HHs financing non-consumption with credit	0.183	0.172	0.139	0.151	
Value of farm, land, business & HH assets, Rp. mn.	31.654	12.636	28.292	14.285	
Savings (deposits, gold, etc), March 1998, Rp. mn.	0.829	0.989	1.060	1.032	
Credit taken or outstanding, 1998-99, Rp. mn.	0.772	0.803	0.347	0.240	
Share of output sold	0.668	0.188	0.515	0.232	*
Share of households using technical irrigation	0.083	0.170	0.336	0.360	***
Share of households using simple irrigation	0.118	0.169	0.118	0.123	
Household head education	4.676	1.324	5.730	1.066	**
Share of cultivated area using HYV seeds	0.341	0.223	0.449	0.277	
Share of cultivated area planted in rice	0.247	0.216	0.389	0.293	
Share of cultivated area planted in corn	0.119	0.170	0.063	0.103	
Share of cultivated area planted in dryland crops	0.279	0.271	0.170	0.218	
Share of cultivated area planted in tobacco or sugar	0.049	0.124	0.024	0.065	
Share of cultivated area planted in tree crops	0.305	0.247	0.354	0.320	

Asterisks indicate p-value for t-test of equality of means across groups where
*** indicates p-value <0.01, ** indicates p-value <0.05, and * indicates p-value <0.1.

Table 3.8: Comparison of Means Across Households With and Without Labor Exchange in Labor Exchange Villages, 1998-99

Variable	Labor Exchange Households (N=189)		Non-Labor Exchange Households (N=584)		
	Mean	Std. Err.	Mean	Std. Err.	
Area planted, Ha	2.154	0.215	1.655	0.183	**
Area owned	1.272	0.164	1.254	0.167	
Ln avg. absolute deviation from village mean plot size	-1.260	0.151	-1.337	0.158	
Share of planted area owned	0.772	0.044	0.832	0.025	
Share of village plots within 10% of plot's area, avg.	0.129	0.015	0.110	0.010	
Has some credit or savings	0.767	0.053	0.546	0.049	***
Has some savings, 3/98	0.476	0.122	0.288	0.043	
Has some credit outstanding, 1998-99	0.423	0.078	0.382	0.044	
Savings, March 1998, Rp. mn	1.430	0.428	0.751	0.190	*
Credit taken or outstanding, 1998-99, Rp. mn	0.484	0.149	0.640	0.197	
Value of rotating savings pool, 1998-99, Rp. mn	0.265	0.155	0.106	0.031	
Value of land owned net of land credit, 3/98, Rp. mn	22.103	3.167	27.259	2.986	
Value of business assets net of bus. credit, 3/98, Rp. mn	1.031	0.273	1.000	0.232	
Value of HH assets net of HH credit, 3/98, Rp. mn	2.767	0.599	3.364	0.713	
Value of farm assets net of farm credit, 3/98, Rp. mn	2.365	0.446	1.808	0.464	*
Value of output per hectare, Rp. mn	3.928	0.885	6.042	1.304	**
Share of output sold	0.568	0.082	0.719	0.034	*
Number of plantings	1.681	0.136	1.667	0.116	
1 if use technical irrigation	0.081	0.047	0.087	0.039	
1 if use simple irrigation	0.074	0.026	0.113	0.037	
Share of cultivated area using HYV seeds	0.387	0.115	0.342	0.043	
Household size	4.677	0.092	4.723	0.141	
Household head age	46.233	1.013	49.702	0.805	***
Household head education	4.709	0.479	4.683	0.263	

(continued…)

Table 3.8 (continued)

Variable	Labor Exchange Households		Non-Labor Exchange Households		
Share of cultivated area planted in rice	0.328	0.095	0.227	0.044	
Share of cultivated area planted in corn	0.190	0.074	0.104	0.031	
Share of cultivated area planted in dryland crops	0.196	0.051	0.312	0.066	**
Share of cultivated area planted in tobacco or sugar	0.057	0.044	0.049	0.028	
Share of cultivated area planted in tree crops	0.230	0.051	0.307	0.064	
Household on-farm labor hours per Ha	967.212	203.404	962.955	140.714	
Hired on-farm labor hours per Ha, incl. labor exchange	391.853	55.888	336.135	48.263	
Household off-farm labor hours in agriculture	256.168	69.607	365.425	60.780	

Asterisks indicate p-value for t-test of equality of means across groups where
*** indicates p-value <0.01, ** indicates p-value <0.05, and * indicates p-value <0.1.

For this sample of farming households in labor exchange villages, holdings of working capital in the form of liquid savings or credit are somewhat limited. Nearly 60 percent of these households reported some savings or credit; 32.8 percent had positive savings and 38.8 percent took loans during the 1998-99 season or were paying outstanding loans. Less than 13 percent of households had both savings and credit, suggesting that few households would protect savings for future use in the face of current and relatively expensive demands for liquidity. As shown in Table 3.8, the evidence on the importance of working capital for the decision to use labor exchange is mixed. Labor exchange households are significantly more likely to have some savings or loans outstanding, which argues against the importance of quantity restrictions in capital markets as a source of labor exchange. Average credit holdings are smaller than in non-labor exchange households, but average savings are significantly larger. Other indicators offer some support for cash constraints being associated with labor exchange use: (i) the average value of land and household asset holdings is larger for non-labor exchange households (though not significantly so); (ii) yields are substantially higher for farms not using labor exchange, and (iii) the share of output sold is higher on these farms too.

There is also evidence that selection into labor exchange teams is affected by a farmer's plot size and choice of crops. Labor exchange households show larger average share of village plots that are roughly the same size as their plots, although the difference in means across cohorts is not significant. Area devoted to dryland crops other than corn is significantly lower on farms using labor exchange and average share of area under rice and corn are higher but not significantly so. Other data show that on 71 percent of plots on which labor exchange was used, rice (43%) and corn (28%) were the commodities with the largest share of the value of output. This probably indicates returns to teamwork in production of these crops, but also is consistent with farmers under labor exchange growing the same crops in order to facilitate reciprocity in the exchange.

Hired labor time employed on farm, from paid labor and exchange labor sources, is higher for households using labor exchange than for other households, but not significantly so. This may indicate some role for labor exchange in relaxing constraints on labor demand imposed by labor or credit market failures. As noted earlier, labor exchange is a large enough source of external (47.9 percent) and total (14.8 percent) labor demand on average for those households that use it that it could play a significant role in relaxing constraints on team labor demand for some of these households.

The prevalence of labor exchange across seasons and labor activities provides further evidence on the role of factor market imperfections in demand for labor exchange. Returning to Table 3.2, the share of labor exchange contracts that took place during the rainy season when labor demand is at its highest (58.2%) is significantly higher than the share of daily wage contracts in the rainy season (38.4%). Part of this greater demand for labor exchange during the rainy season may also derive from its ability to reduce the time devoted to tasks through teamwork. Piece rate and output share contracts, which also encourage faster task completion, are also considerably more prevalent in the rainy season than daily wage contracts.

Table 3.9 shows the distribution of labor exchange arrangements and other labor contracts across tasks. For labor exchange, 43 percent of the arrangements occurred in planting activities, 24 percent in harvesting, 13 percent in weeding and 12 percent in plowing. Although most of these contracts took place during planting and harvesting activities when labor demand is typically greatest, a considerable share occurred during periods when demand for labor is quite weak. The prevalence of labor exchange teams during planting (at 14 percent of all planting contracts for outside labor) probably reflects some returns to teamwork for this activity, but is also consistent with cash constraints. Part of the reason that reliance on labor exchange is not greater for harvesting tasks is surely due to output share contracts for harvesting, another labor arrangement that enables farmers to eschew cash payments. Harvest share contracts can also be used to pay planting labor through tied labor contracts, called *ceblokan* on Java, in which workers agree to participate in both planting and harvesting activities for an elevated share of the output. Because of the significant delay in receipt of payment for planting services, this type of contract is often unattractive to workers, but may be more prevalent than labor exchange in regions where the landless labor force is relatively large.

An important source of transactions costs for participating in a labor exchange team is the time and other costs of finding teammates. The pool of potential teammates is usually restricted to neighboring farmers producing the same crops on plots of similar size. Goethals (1967) notes that in West Sumbawa in Indonesia, farmers seek teammates for labor exchange with similar sized plots in order to reduce the need for side payments from farmers with larger plots to those with smaller ones. This alone is evidence that participants in labor exchange may be cash constrained. The location of a farmer's plot in the local distribution of plot size may determine whether he has any potential teammates and the cost of finding them. The causation may also run the other way. The historical reliance on labor exchange teams in some areas may help to explain why farmers growing the same commodities in a village tend to carve out plots of similar size.

Table 3.9: Distribution of Labor Contracts by Activity, 1998-99

Type of Contract	Task: Land prep	Plow	Plant	Weed	Harvest	Mill	Total
Daily wage	431	1,437	1,615	1,662	1,296	190	6,631
Piece rate	103	824	426	153	365	168	2,039
Output share	1	3	4	6	577	37	628
Tied	2	3	78	6	8		97
Exchange	31	95	358	106	202	34	826
Daily team			1	2	3	2	8
Piece team	3	31	128	43	160	8	373
Share team		1			267	2	270
Tied team				5	2		7
Other	10	13	20	21	21	11	96
Total	581	2,407	2,630	2,004	2,901	452	10,975

In general, labor exchange will be less common on plots in the tails of the distribution of plot size because farmers of these plots will have fewer potential teammates with plots of similar size. In the lower tail of the distribution, plots may also be too small for returns to teamwork to take hold. Farmers owning plots in the upper tail of the distribution may have larger farms overall with better access to credit, so these farmers may be less likely to use labor exchange as well. The distribution of plot size for plots on which labor exchange is used should lie to the left of the plot size distribution for plots not using labor exchange. The distribution of plots on which labor exchange is used also should have lower variance.

Figure 3.1 presents nonparametric kernel density estimates of the distribution of plot size by village for plots on which labor exchange was used in any activity in 1998-99 and for all other plots. These kernel density estimates were obtained using the Epanechnikov kernel function,

$$K[z] = \begin{cases} .75\left(1-.2z^2\right)/\sqrt{5} & if\,|z| < \sqrt{5} \\ 0 & \text{otherwise.} \end{cases}$$

In deriving the kernel density estimates, the bandwidth was allowed to vary with the number of observations available in each village. Land distributions are presented by village because most potential labor exchange teammates are farmers in the same or neighboring villages as high travel costs quickly render labor exchange teams unprofitable. Land distributions by labor exchange use are only presented for those villages in which labor exchange is used and where there are at least 12 plots in each category. Table 3.10 shows the number of plots in each village in Figure 3.1 by labor exchange use.

Several patterns emerge in the graphs in Figure 3.1. The distribution of plot size for labor exchange plots generally lies to the left of the distribution of non-labor-exchange plots in six out of nine of the villages. In the middle panel in Figure 3.1 for Sukadamai village on Sumbawa Island in West Nusa Tenggara, the area distribution of labor exchange plots shows substantially less dispersion than that of non-labor-exchange plots. However, the opposite is true for the panel just to the left of that one, which shows the plot size distributions in Plampang village, also on Sumbawa Island. Although we expect the upper tail of the distribution to be smaller for labor exchange plots, this is not true in several of the villages. This may be the case in some villages with small farms, where even the largest plots are small enough to accommodate rotating labor exchange teams. In South Sulawesi, the use of labor exchange on large plots may suggest that some farmers there are using the larger festive labor exchange teams.

Figure 3.1: Distribution of Plot Size by Labor Exchange Use, Selected Villages, 1998-99

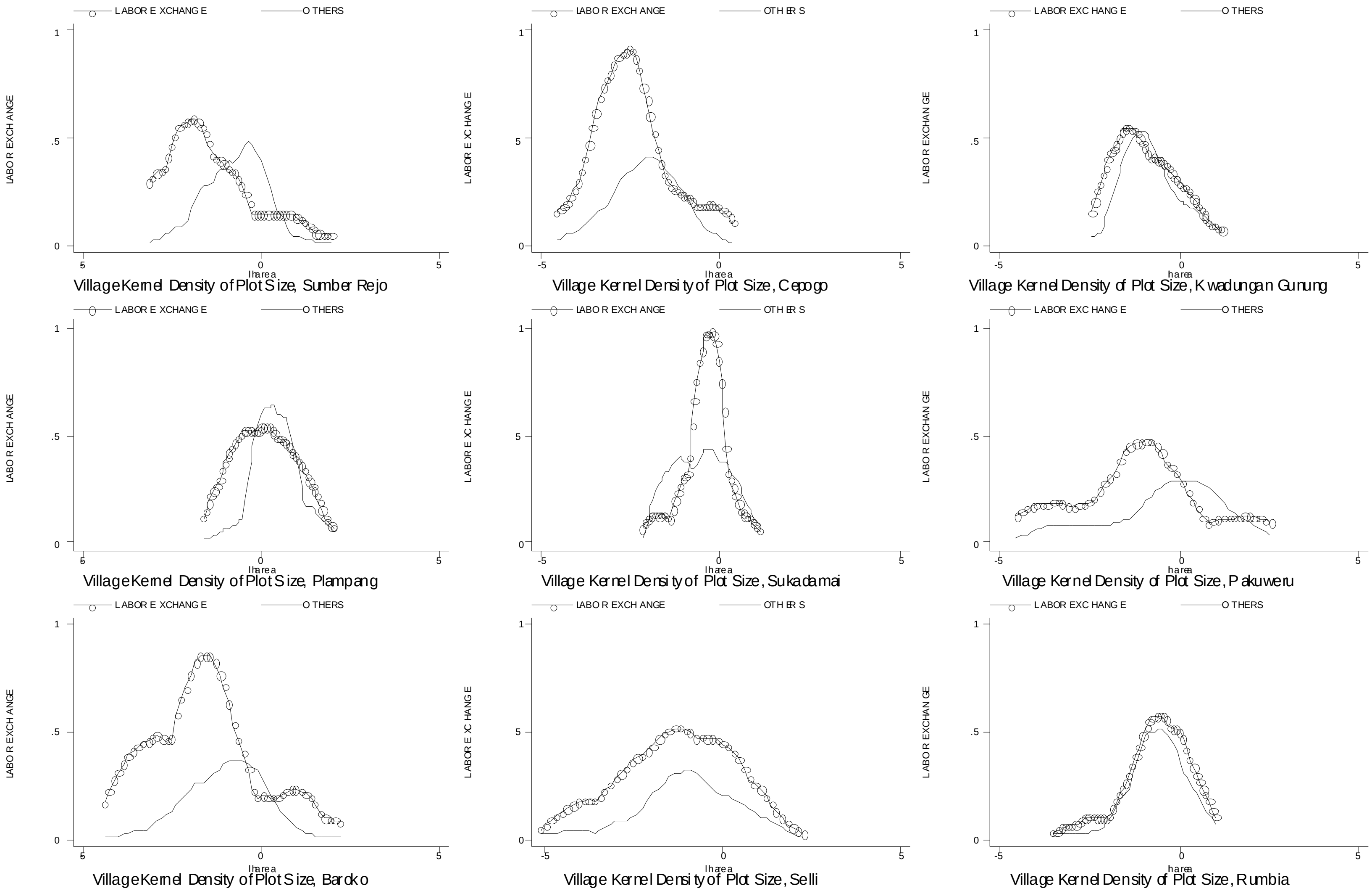
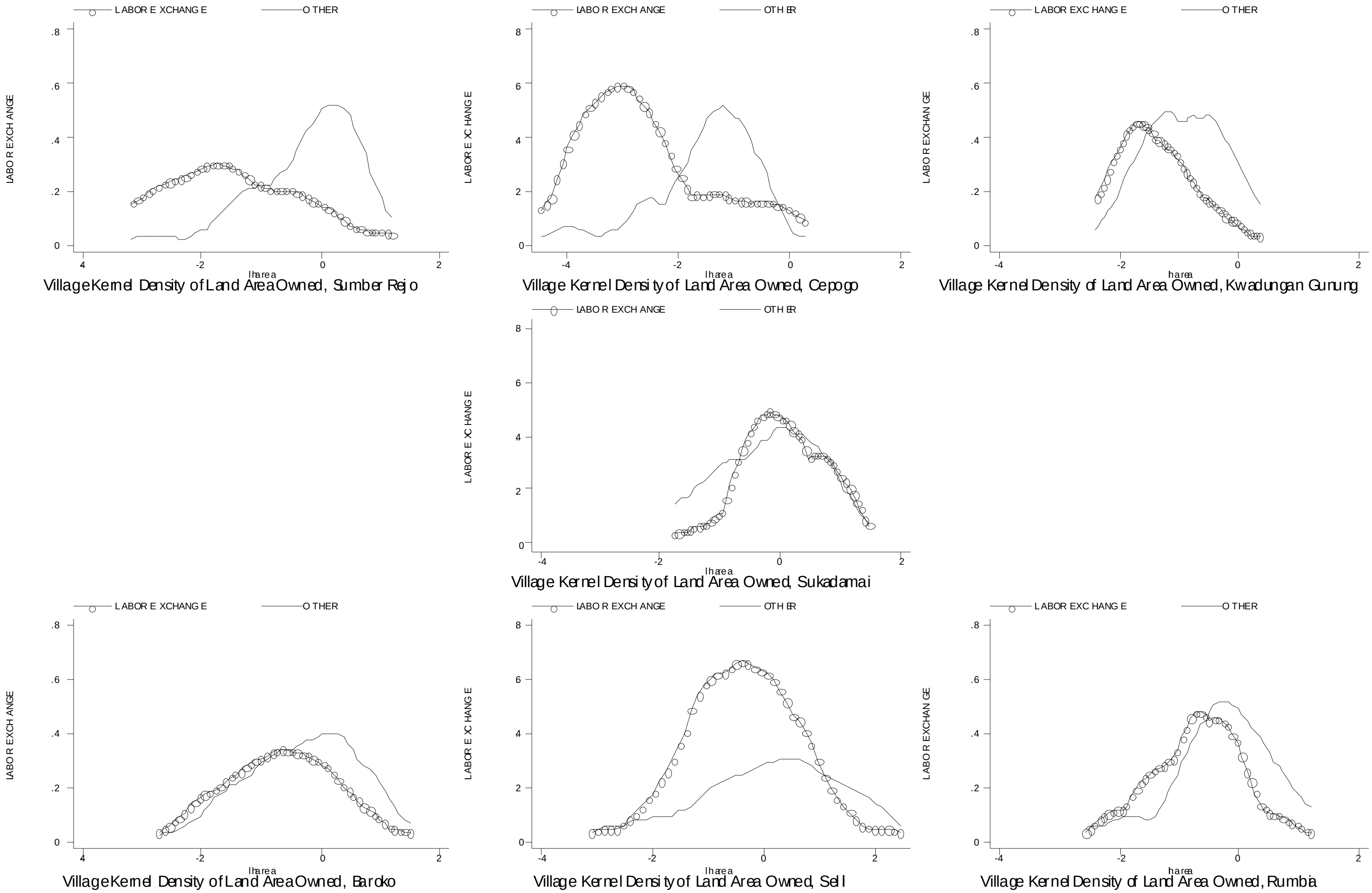


Table 3.10: Distribution of Plot Size in Selected Labor Exchange Villages, 1998-99

Province	Village	Number of Plots using Labor Exchange	Number of Plots without Labor Exchange	Share of Plots using Labor Exchange	Average Plot Size (Hectares)
Lampung	Sumber Rejo	16	63	0.203	0.696
Central Java	Cepogo	16	56	0.222	0.194
	Kwadungan Gunung	22	25	0.468	0.611
W. Nusa Tenggara	Plampang	12	61	0.164	1.739
	Sukadamai	25	58	0.301	0.744
N. Sulawesi	Rumoong Atas	16	44	0.267	1.348
S. Sulawesi	Baroko	18	63	0.222	0.600
	Selli	46	45	0.505	0.857
	Rumbia	30	40	0.429	0.769

If households with the largest farms are less likely to use labor exchange because of greater access to capital, as predicted by the model in Chapter 2, this effect should be greatest in a comparison of the distributions of total farm size by labor exchange use. Figure 3.2 compares the distribution of total land area owned for farmers that used labor exchange on any plot to that of farmers that did not use labor exchange at all. The panels for two villages are omitted because insufficient farm-level observations were available for reliable kernel density estimates in these villages. The graphs in Figure 3.2 show clearly that owners of the largest farms are less likely to participate in labor exchange.

Figure 3.2: Distribution of Land Area Owned by Labor Exchange Use, Selected Villages, 1998-99



4 Empirical Evidence of Determinants of Participation in Agricultural Labor Exchange

4.1 Introduction

The model of labor exchange with imperfect factor markets developed in Chapter 2 generated several testable hypotheses about how endowments, technology and market imperfections affect demand for agricultural labor exchange. In particular, the model showed how capital endowments, returns to teamwork and search costs for labor transactions determine the modes of production a farmer selects by optimally solving his joint land-labor decision problem. The model also explains the conditions that determine the switch points between two modes of production. These switch points serve as the thresholds in a farmer's decision to use labor exchange. It is this labor exchange participation decision that is the primary research topic to be addressed in this chapter. Although the factors affecting the level of demand for labor exchange are of considerable interest, the first line of inquiry into this mostly unexamined non-market labor arrangement should concern the economic motivations for its existence.[52] With this goal in mind, this empirical investigation begins with its microeconomic foundations, at the individual farmer's decision to participate in labor exchange teams.

[52] I do not attempt to explain the complete pattern of modes of production that arise in the model in Chapter 2. With twelve modes of production, this would be an unwieldy exercise and would detract from the goal of explaining farmers' decisions to use labor exchange. The analysis of the model in Chapter 2 demonstrates a consistency of the effects of endowments of working capital and farm size on the use of labor exchange across several modes of production. Therefore, it is not necessary to identify the determinants of each mode of production in order to explain labor exchange use. Other studies have

In this chapter, I explain a farmer's decision to participate in a labor exchange team using the sample of farmers living in villages with the labor exchange institution in the Indonesian PATANAS survey of 1998-99. I begin by developing an empirical model of the farmer's decision to use labor exchange from the theoretical model in Chapter 2. I then test a number of the hypotheses arising from the theoretical model and the empirical model of the participation decision. Among the results from the theoretical model is that returns to teamwork in production are a necessary condition for agricultural labor exchange. The model also relied on three forms of factor market imperfections to explain labor exchange use: supervision costs for external labor on farm; transactions costs for each type of labor transaction (buying, selling, and labor exchange); and quantity restrictions on access to credit as a constraint on working capital. Another implication of the model is that, despite the rigidities in the labor market, working capital and asset holdings have no effect on demand for labor exchange if there is no constraint on access to credit. However, if the working capital constraint is binding, the effect of working capital holdings on labor exchange use depends on the mode of production, returns to teamwork and the supervision technology. For laborer cultivators using labor exchange, larger working capital holdings increase demand for labor exchange. For self-cultivators or small capitalists using labor exchange, the effect of working capital on demand for labor exchange depends on technology and supervision costs. In particular, working capital is more likely to reduce demand for labor exchange if team size is a weaker substitute for land than is labor time, or if supervision and search costs in labor exchange are high.

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presented empirical evidence of the more concise class structure in the model by Eswaran and Kotwal (1986) (see Sadoulet, de Janvry and Benjamin, 1998).

After developing the empirical model of labor exchange use, I test for the presence of returns to teamwork in production for rice and corn farmers, the sub-sample of farmers most likely to use labor exchange. I then estimate the model of the farmer's decision to participate in labor exchange under various assignment rules of households into working-capital-constrained and -unconstrained cohorts. As a benchmark, I consider the determinants of participation in labor exchange under the assumption that all households in the sample are constrained in access to working capital. The model developed here provides a number of exclusion restrictions on working capital and assets that make it possible to test the validity of this assumption, and the relevance of the model for the sample as a whole. The estimates for the full sample provide substantial support for the model of labor exchange with imperfect factor markets developed in Chapter 2. Nonetheless, if not all households are working capital constrained, these estimates are biased. Next, I consider a reasonable assignment rule to divide the sample into constrained and unconstrained cohorts and test the determinants of participation in labor exchange subject to working capital constraints. Under this assignment rule, a household is working capital constrained in any season if it has no predicted savings, borrowing or lending. I test the robustness of the model to this assignment rule in two ways. First, I estimate the model again under an assignment rule that classifies more of the sample as working capital constrained, creating an intermediate case between the "all are constrained" and "no working capital" assignment rules. Second, I estimate the model using a procedure in which the assignment of households to the constrained and unconstrained regimes is based on the statistical properties of the data in an application of the EM algorithm of Dempster, Laird, and Rubin (1977). This algorithm treats the problem of unobserved working capital constraint status as a missing data problem. Starting with predicted constraint status from the model with the "no working capital" assignment rule, the algorithm re-estimates the labor exchange and working capital determinants. This creates a new assignment of observations to constraint regimes, and the process is repeated through iteration. I show that the complete-data version of this model satisfies the requirements for the algorithm to converge. Despite some limitations in applying the algorithm brought on by the data and by the shape of the complete data likelihood function, I am able to derive new estimates from the algorithm that improve the model in a likelihood sense. I show that some of these estimates also improve the ability of the empirical strategy to satisfy the predictions of the theoretical model of labor exchange.

4.2 Empirical Implementation of the Model of Labor Exchange

In the model from Chapter 2, the decision to use labor exchange is a function of transactions and supervision costs in the labor market; rationing in the credit market; the production technology; endowments of land, savings and household size; and prices of land and labor. Such a model would be sufficient for the purposes of measurement of participation in, and demand for, paid labor under the common assumption that there is an infinite supply of labor available at the market wage rate. In the case of labor exchange, no market price exists and the supply of potential teammates in exchange labor is typically far less robust than the availability of paid laborers. The potential supply of exchange labor available to a given farmer is a function of the distribution of land within the surrounding area, particularly the number of other households with control rights over plots of similar size to his own. Empirical implementation of this model requires accounting for these supply considerations in the market for labor exchange.

The supply of potential teammates affects search costs for labor exchange. For the *i*th farmer with plot size A_i, the pool of potential teammates includes all farmers at or near the same location in the village distribution of land, say $g(A_i)$ where g is the village probability density function of plot size. Figure 3.1 in Chapter 3 graphs these plot size distributions for several villages in the Indonesian sample, with plots on which labor exchange was used separated from other plots. These graphs illustrate the size of the pool of potential teammates across the distribution of plot size. The search costs are a function of the probability, $\Pr(n_E \mid g(A_i))$, that at least n_E other farmers with similar plot size will resolve their land and labor allocation problem in equation (2.6) in favor of participating in labor exchange.[53] The search costs for participation in labor exchange become

$$c_E = c_E(\Pr(n_E \mid g(A_i))).$$

[53] I do not investigate the matching problem inherent in constructing labor exchange teams from the pool of potential teammates at a given plot size. This problem involves consideration of the size of the teammate pool and the optimal team size. I do not devote attention to this interesting coordination problem in part because it is likely resolved through reliance on strength of social ties in practice.

The graphs in Figure 3.1 demonstrate how these search costs increase as plot size moves into the tails of the distribution. They also show how these costs vary substantially by village, based on the local distribution of land. As shown in Chapter 2, in the presence of returns to teamwork in production, a farmer with a given endowment of working capital will choose to participate in a labor exchange team if

(4.1) $$c_E\left(\Pr\left(n_E \mid g\left(A_i\right)\right)\right) < c_M + \frac{c_F}{T}.$$

Accounting for the uncertain probability of finding teammates in this way makes the decision to participate in labor exchange stochastic through the effects on condition (4.1). This decision can be represented in a probit model in which participation in a labor exchange team is a function of technology, household endowments, prices, and the distribution of land in the village. As the model in Chapter 2 has shown, the effect of these variables on the decision to use labor exchange will depend on whether the household is constrained in its holdings of working capital. This suggests a switching regression framework in which the sample is separated into working capital-constrained and -unconstrained households with separate probit regressions estimated for each cohort. Therefore, the empirical model takes the form

(4.2.a) $$Y_{1i}^* = X_{1i}\beta_1 + \varepsilon_{1i} \quad \text{if} \quad u_i > -W_i\gamma, \text{ and}$$

(4.2.b) $$Y_{2i}^* = X_{2i}\beta_2 + \varepsilon_{2i} \quad \text{if} \quad u_i \le -W_i\gamma,$$

where Y_{1i}^{*} is a latent variable representing net benefits from participating in labor exchange if the household is working capital constrained and Y_{2i}^{*} is similarly defined for unconstrained households. Also, X_{1i} and X_{2i} are vectors of regressors that explain the decision to use labor exchange for constrained and unconstrained households, respectively; W_i contains variables explaining whether a household is working capital constrained; β_1, β_2, and γ are parameters to be estimated; and $\varepsilon_{1i}, \varepsilon_{2i}$, and u_i are mean zero error terms. With Y_{1i}^{*} and Y_{2i}^{*} as latent variables and the working capital constraint condition unobserved, all that is observed is an indicator variable for whether the household uses labor exchange,

$$(4.3) \qquad y_i = \begin{cases} 1 \text{ if } \left(\varepsilon_{1i} > -X_{1i}\beta_1 \text{ and } u_i > -W_i\gamma\right) \text{or} \left(\varepsilon_{2i} > -X_{2i}\beta_2 \text{ and } u_i \leq -W_i\gamma\right) \\ 0 \text{ if } \left(\varepsilon_{1i} \leq -X_{1i}\beta_1 \text{ and } u_i > -W_i\gamma\right) \text{or} \left(\varepsilon_{2i} \leq -X_{2i}\beta_2 \text{ and } u_i \leq -W_i\gamma\right). \end{cases}$$

This yields a switching regression model of the decision to participate in labor exchange depending on whether the household is constrained in holdings of working capital. Assume that all households bringing outside labor on farm are constrained in the sense of facing moral hazard and search costs for each type of labor. Also assume that the vector of error terms in the labor contract choice and switching regressions are jointly normally distributed

$$\left(\varepsilon_{1i}, \varepsilon_{2i}, u_i\right)' \sim N\left(0, \Sigma\right)$$

with

$$\Sigma = \begin{bmatrix} \sigma_{11} & \sigma_{12} & \sigma_{1u} \\ \sigma_{12} & \sigma_{22} & \sigma_{2u} \\ \sigma_{1u} & \sigma_{2u} & 1 \end{bmatrix}.$$

That is, error terms may be correlated across equations in (4.2). Otherwise, if $\sigma_{1u} = \sigma_{2u} = 0$, this model is an exogenous switching regression. Because the working capital constraint is not observed, the model represents a simultaneous equations endogenous switching regression model with unobserved selection point.[54] This model has been applied in settings where the dependent variable in the equation of interest is continuous by Dickens and Lang (1985), Morduch and Stern (1997), and Hu and Schiantarelli (1998). Applying such a model to the discrete choice setting is a new contribution of this research. Kimhi (1999) implemented an endogenous switching regression model for discrete dependent variables, but where the point of selection for the switching equation is observed.

The likelihood function corresponding to the model in (4.2)-(4.3) for the *i*th farm is

(4.4)
$$\begin{aligned} LLF_i^I &= L^I\left(\beta,\gamma,\sigma_{1u},\sigma_{2u} \mid y, X, W\right) \\ &= \prod_{y_i=1}\left[\Phi_2\left(X_{1i}\beta_1, W_i\gamma, \rho_{1u}\right) + \Phi_2\left(X_{2i}\beta_2, -W_i\gamma, -\rho_{2u}\right)\right]\cdot \\ &\quad \prod_{y_i=0}\left[\Phi_2\left(-X_{1i}\beta_1, W_i\gamma, -\rho_{1u}\right) + \Phi_2\left(-X_{2i}\beta_2, -W_i\gamma, \rho_{2u}\right)\right]. \end{aligned}$$

[54] This type of model is also referred to as a mixture model because the population is treated as consisting of subpopulations with distinct regression coefficients.

where X is the matrix whose columns are the non-redundant variables in X_1 and X_2. The parameters to be estimated in this model are β_1, β_2, γ, σ_{11}, σ_{22}, σ_{1u}, and σ_{2u}. Because Y_{i1}^* and Y_{i2}^* are latent variables, σ_{11} and σ_{22} are not separately identified from the structural slope coefficients, so these are normalized to one. Notice that σ_{12} does not appear anywhere in the likelihood function and so is also not identified. Maddala (1983) notes that although the error vector has a trivariate distribution, a function of bivariate distributions on a pair of the error terms is estimated. This is the cause of the failure of identification of σ_{12}. However, this should not raise concerns about the completeness of this model. Such "reductions" in the order of the problem are common in the discrete choice setting.

Identification of the likelihood function in (4.4) requires that at least one variable in X_1 does not appear in X_2, or *vice versa*. Estimation of this likelihood function is a difficult exercise and direct estimation may not be feasible. In order to make the estimation more tractable, I simplify the likelihood function by assigning observations to the constrained or unconstrained regimes based on their holdings of working capital in the form of savings or credit. The assignment rule takes the form

$$k_i = \begin{cases} 1 \text{ if } u_i > -W_i\gamma \\ 0 \text{ if } u_i \leq -W_i\gamma. \end{cases} \tag{4.5}$$

After applying this rule, the likelihood function takes the form

(4.6)

$$
\begin{aligned}
LLF_i^C &= L^C\left(\beta,\gamma,\sigma_{1u},\sigma_{2u} \mid y,k,X,W\right) \\
&= \prod_{\substack{y_i=1 \\ k_i=1}} \Phi_2\left(X_{1i}\beta_1, W_i\gamma, \rho_{1u}\right) \prod_{\substack{y_i=1 \\ k_i=0}} \Phi_2\left(X_{2i}\beta_2, -W_i\gamma, -\rho_{2u}\right) \cdot \\
&\quad \prod_{\substack{y_i=0 \\ k_i=1}} \Phi_2\left(-X_{1i}\beta_1, W_i\gamma, -\rho_{1u}\right) \prod_{\substack{y_i=0 \\ k_i=0}} \Phi_2\left(-X_{2i}\beta_2, -W_i\gamma, \rho_{2u}\right).
\end{aligned}
$$

In estimation, I begin with an arbitrary assignment rule for (4.5) as discussed in the introduction to this chapter. I then derive improved estimates by applying the EM algorithm, using the idea that the likelihood function L^C in (4.6) can be treated as the complete data analogue to the incomplete data problem inherent in the likelihood function L^I in (4.4). Using this algorithm, parameter estimates and predicted probabilities that each household is constrained are obtained in an iterative procedure that reflects the statistical properties of the data.

Zeldes (1989) was the first to use the general approach of estimating a model of liquidity constraints by applying an arbitrary assignment rule in his study of the effects of liquidity constraints on consumption. Using U.S. data, Zeldes classified a household as liquidity constrained if it had less than two months of income held in liquid assets. In my approach to defining the assignment rule, I tried to identify a liquidity constraint threshold that is appropriate to rural agricultural households in a developing country where access to credit is generally more restricted than in the U.S. Following Giné (2001), I define working capital based primarily on its distinction from fixed capital. Fixed capital remains in place after agricultural production is completed, while working capital is consumed in the production process and is fungible across uses. The two sources of working capital are savings and credit. In the Indonesian data, liquid savings includes the value of bank deposits, bonds, cash, jewelry, and other stored valuables. Other forms of savings include stored rice and other food for consumption and stored crops. Constraints on working capital operate primarily through restrictions on access to credit. However, these constraints are made manifest in the household in the absence of working capital in any form because it is fungible. Therefore, in an attempt to separate the sample by working capital constraint status, I classify a household as working capital constrained in each season if it has no savings, borrowing or lending, either outstanding or initiated during the season. The variable indicating working capital constraint status based on this assignment rule is treated as endogenous in the estimation. In constructing these cohorts, I begin with the sub-sample of households with no savings or debt in each season and remove those that are currently lending money, since these households would have a higher probability of using the funds themselves if they were constrained. This assignment rule for working capital constraints is similar to one used by Jacoby (1994) in an application to schooling decisions in Peru. I also consider a more relaxed threshold for classifying households as working capital constrained. The primary shortcoming of this approach is the arbitrariness of the sample separation. Although the theoretical model underlying such problems typically leads to exclusion restrictions that can be used to test the accuracy of the predicted assignment of observations to regimes, robustness tests are needed to ensure that another separation of the sample would not lead to a higher value for the likelihood function. These tests are limited in most cases, since there are 2^n possible separations of the data. This highlights the attraction of the EM algorithm for this type of problem. The EM algorithm provides a likelihood-based methodology for selecting alternative separations of the data. The algorithm iterates between finding parameter estimates that maximize the likelihood function for the current separation of the data, and choosing an alternative separation based on the predicted probability of belonging to a given regime. The conditions under which this procedure converges toward a maximum are discussed below.

I estimate the probability of being working capital constrained as a function of household assets, local interest rates and demand for credit, and household demographics that proxy for demand for credit for consumption purposes. Out of 849 households primarily engaged in farming with complete data in the sample of households living in labor exchange villages, 361 had no borrowing, savings, or lending as they began production in the 1998-99 agricultural year. The classification of households as constrained is based on having no borrowing, savings, or lending by season. These seasons include the rainy season (from October 1998 – March 1999), the dry season (from April 1998 – September 1998) or the entire crop year for annual crops (April 1998 – March 1999). This definition of constrained households has considerable intuitive appeal, since an unconstrained household is likely to have either savings or credit use. In this approach to identifying constrained households, I am intentionally conservative in selecting households into the constrained sub-sample that are very likely to be constrained. I expect the misclassification of households based on this assignment rule to be heavily biased toward constrained households being classified as unconstrained. This approach is intended to provide precise estimates of the labor exchange decision for constrained households.

However, as a benchmark for this conservative approach, I first estimate the labor exchange decision assuming all households are constrained.

Results of these estimation procedures are presented below. Even for these rather unsatisfactory approaches to separating the sample by working capital constraint, the results offer considerable support for the model of labor exchange under working capital constraints presented in Chapter 2. Before estimating the model of determinants of labor exchange, I begin by verifying the presence of returns to teamwork in agricultural production in the Indonesian sample.

4.3 Returns to Teamwork

The model presented in Chapter 2 shows that returns to teamwork are a necessary condition for use of labor exchange teams. In this section, I test for the presence of returns to teamwork in the Indonesian data. There has been little empirical research into the productivity advantages of teams, despite a large theoretical literature. The limited evidence that exists generally finds positive returns to teamwork, but in production settings quite different from agriculture.[55] I am not aware of any systematic evidence for or against a productivity advantage for teams in agricultural work.

[55] See Hamilton et al (2003) for positive evidence for garment workers. They cite a handful of other studies with evidence for law firms, medical practices, and other services firms and for manufacturing.

The test of returns to teamwork used here involves estimation of an agricultural production function. The production technology is assumed to be Cobb-Douglas and is estimated in log-log form. One approach to identifying returns to teamwork in this estimation is to disaggregate hired labor into team labor and other hired labor and test that team labor has higher productivity. However, such an approach may confound team effects and incentive effects if team labor is more likely to be performed under piece rate or output share contracts than wage contracts, which have lower effort incentives (Seiler, 1984; Paarsch and Shearer, 2000; Lazear, 2000; and Oettinger, 2001). Indeed, for the sample under consideration here, daily wages make up 60.7 percent of casual non-team labor contracts. High incentive piece rate and output share arrangements make up only 36.5 percent of these contracts, but they constitute 46.6 percent of team labor contracts. Exchange labor represents another 42.8 percent of team contracts. The characteristics of exchange labor arrangements present both weaknesses and strengths in terms of effort incentives. Weaknesses include technical difficulties of monitoring team production and the erosion of incentives on farms late in the rotation of exchange. However, the reciprocity inherent in labor exchange in a village setting characterized by multiple interactions by agents across activities over time suggests that incentives arising from reciprocity and reputation may be quite strong. This evidence suggests that team labor contracts may include higher effort incentives on average, depending on the strength of effort reciprocity operating in labor exchange. In order to remove the incentive component to the test for returns to teamwork, the production function is estimated with hired labor hours disaggregated into *non-team* piece rates, piece rate *teams*, and other hired labor including labor exchange. The null hypothesis of no returns to teamwork is rejected if piece rate team labor is more productive than other piece rate labor.

A practical problem with estimating a Cobb-Douglas production function in the common log-log form is the treatment of zero values for any of the inputs since all factors are essential under this technology. This problem is particularly important in this case where labor is disaggregated into household labor and three forms of hired labor; many farmers do not use all four types of labor. As a partial solution to this problem I follow MaCurdy and Pencavel (1986) and Jacoby (1993) and add a one to all inputs except land before taking logs. The use of a shift parameter appears to provide an effective remedy as long as it does not have a significant effect on the relative productivity of the various sources of labor, which is the main concern here. I address the appropriateness of this specification in the discussion of results below.

The dependent variable in the production function estimation is the log value of output. Inputs include the three kinds of hired labor, household labor hours, non-labor cost (including fertilizer, pesticides, seeds, etc.), area planted, and the value of farm equipment. Dummy variables for two forms of irrigation (technical and simple) are included, as is a dummy for whether the plot is rated as dryland, which indicates soil quality. For the sample used here, 74.8 percent of the plots were wetland and 18.7 percent were dryland. Dryland plots typically have lower yields. Household head age and education are also used as regressors to control for differences in managerial ability. Season and province dummies are also included in the estimation.

Complete production data are available for each household by plot and season, so individual plots are treated as the unit of observation. As noted in Chapter 3, labor exchange is primarily used in rice and corn production. These two crops were the primary commodity (measured by value of output) on over 70 percent of the 329 plots on which labor exchange was used in 1998-99. The next most important crop on which labor exchange was used was garlic, which represented only 4.6 percent of labor exchange plots. Therefore, in order to measure returns to teamwork for potential users of exchange labor, the sample was restricted to those plots on which rice or corn represented at least 50 percent of the value of production. The sample was also restricted to include only plots on which some non-household labor was used. This resulted in a sample size of 1031 plots.

Several estimators of the production function are used to test for returns to teamwork. Least squares is employed as a point of reference, although it is biased if there are unobservable household or plot characteristics that are correlated with the inputs or if farmers simultaneously choose input and target output levels. In order to address the resulting bias, an instrumental variables estimator is also used. The four labor variables and non-labor cost are treated as endogenous in the IV estimation. I also investigate the potential endogeneity of area planted. Most farmers in the sample do not deviate from their land endowments when deciding how much land to plant: for 69 percent of the plots in the sample, the area planted is equal to the area owned. This suggests some imperfection in land rental markets, which might justify treating area planted as exogenous in a particular season.

The set of instruments used in IV estimation includes village price data and other village and household characteristics that affect factor demand. Prices include village averages of male wage rates, the price of rice, and interest rates on loans taken by respondent households. The share of adults in the village working as agricultural laborers in the 1998 census is used to represent village labor supply conditions. Using the 1998 census data to construct this variable creates a more complete measure of local labor supply than one based on the later 1998-99 sample data and also ensures that the variable pre-dates current labor demand. By this construction, the share of adults working as agricultural laborers should be a good instrument because it will be highly correlated with the labor demand variables, but will be uncorrelated with unobserved contemporaneous shocks to output that are captured in the error term. Another instrument is the village median distance to the market for agricultural crops, which also exogenously affects demand for factors. The share of village land area planted in rice (constructed from households surveys) should affect prices, and therefore demand, for fertilizer and other factors. Exogeneity of this instrument requires that crop choice is determined primarily by technological factors such as soil quality and rainfall, and not because of complementarities in marketing and production across households. An instrument for area planted is a dummy variable for whether the household has inherited any land, which is primarily a function of birth order in Indonesia and so is likely to be exogenous. Finally, several variables for the age and gender composition of household members are included as factors determining the allocation of household labor time between farming and other activities. At least for working-age household members, the relevant fertility decisions that determined the age composition of household members occurred sufficiently far in the past that the number of these individuals is plausibly exogenous. Below, I provide several tests of the relevance and exogeneity of these instruments.

The OLS and IV estimators are valid only under the assumption of independence of error terms across observations. In order to address the possibility of correlation in error terms across plots within the same household, a random effects instrumental variables model was also estimated. Here the data represent an unbalanced panel because the number of plots and seasons of cultivation varied by household. Finally, the production function is also estimated in a model with village fixed effects to rule out the possibility that a finding of positive returns to teamwork arises only because piece rate teams are more common in villages with high average productivity.

The production function estimates are presented in Table 4.1.[56] Parameter estimates differ across the four models, although the estimates are broadly similar in the random effects and pooled IV models. A Hausman test for joint exogeneity of the four labor variables and non-labor cost rejected the OLS estimates in favor of the pooled IV estimates with a p-value of .0013. Also a test for overidentifying restrictions using Hansen's J-statistic for the pooled IV estimator yielded a p-value of .9109, failing to reject the validity of the instruments. A separate issue concerns whether the set of

[56] Results of the first stage regressions predicting the endogenous labor and non-labor cost variables in the IV and random effects IV models are presented in Appendix C.

instruments is highly correlated with the endogenous labor and non-labor costs variables. Bound, Jaeger and Baker (1995) note that weak instruments in this sense can lead to inconsistency in IV estimates and finite sample bias. They suggest calculating the partial R-squared and conducting an F-test on the joint significance of “excluded” instruments, those not present as regressors in the production function. These statistics are presented at the bottom of Tables C.1.1-C.1.5 for the first-stage estimates of the labor and non-labor cost variables for the pooled IV model. The partial R-squared on excluded instruments is quite low for the household labor hours equation (partial R^2=.039) and the other hired labor hours equation (partial R^2=.054), but this statistic improves for the equations for non-team piece rate labor, piece rate team labor and non-labor cost to .089, .129, and .162, respectively. The somewhat higher partial R^2 for the non-team piece rate and piece-rate team equations are reassuring given the importance of these variables in the test for returns to teamwork. The F-test for significance of the excluded instruments rejects that these instruments are jointly zero a p-values below .001 for all five factor equations. Overall, these results indicate a fairly strong set of instruments for the pooled IV model.

Finally, based on a regression not reported here in which area planted was added to the list of endogenous variables, a Hausman test failed to reject the exogeneity of area planted. Similar tests lead to the conclusion that the random effects IV estimator is preferred to the OLS estimator but could not reject the pooled IV model for the random effects IV model.

The results in Table 4.1 offer strong evidence of returns to teamwork for this sample of rice and corn farmers. As shown from the hypothesis tests for returns to teamwork presented in Table 4.1, the contribution to production from piece rate team labor is significantly greater than that of other piece rate labor for all four estimators, though weakly so for the one with village fixed effects. In the preferred random effects specification in column 3, the elasticity of output with respect to piece rate team labor is 0.80 compared to an output elasticity of non-team piece rate labor of 0.08. The marginal products of non-team piece rate labor and team piece rate labor calculated at the mean of the data are also presented at the bottom of Table 4.1. These results show a substantial productivity advantage at the margin from labor organized in teams.

I now address a possible concern, raised earlier, that the approach to dealing with zero-valued inputs in this specification—adding a shift parameter equal to one to non-land inputs before taking logarithms—may affect the validity of the test of returns to teamwork. The need for the shift parameter arises because zero-valued inputs violate the essentiality assumption for factors of production under the Cobb-Douglas functional form. One concern is that this apparent violation of the essentiality assumption will produce unreliable estimates of relative factor productivity using this functional form. Employing an alternative functional form that does not assume essentiality, such as the Generalized Leontief, would test the restrictiveness of the Cobb-Douglas production function. However, flexible functional forms of this type require estimation of a much larger number of parameters, which can lead to problems of multicollinearity. Facing these alternatives, I preferred to use the Cobb-Douglas functional form and investigate the potential implications of the shift parameter on the estimates of factor productivity and the hypothesis test for returns to teamwork.

The role of the shift parameter is to preserve the zero-valued observations in the estimation. A shift parameter valued at one is attractive because it returns zero-valued observations to zero after taking logs. However, the use of a shift parameter in this specification raises two possible concerns for the test of returns to teamwork: (i) that including the zero-valued observations in the estimation distorts the measurement of factor productivity and (ii) that the size of the shift parameter relative to the uncensored data may bias productivity estimates. In the data used to generate the estimates in Table 4.1, more than half of the observations use no non-team piece rate labor and roughly ninety percent use zero piece rate team labor. The first concern raised here is that a large number of censored observations for piece rate team hours may bias estimates of productivity for this factor upward. To address this concern, I randomly dropped roughly half of the observations with zero piece rate team hours and estimated the pooled IV model on the remaining data (N=577). The estimated elasticity of non-team piece rate hours was .06 and that of piece rate team hours was .60. A t-test rejects equality of these coefficients (p-value = .020), which suggests that incorporating censored values for the piece rate team labor variable is not driving the finding of positive returns to teamwork. The second concern is the choice of shift parameter. The shift parameter should not be large enough to significantly affect the relative productivity of the labor variables used in the test of returns to teams. For the sample used in estimation, the average number of hours of labor hired under piece rate teams and non-team piece rate contracts for households using each type of labor contract is 55.5 and 73.3 hours, respectively. Adding 1 to these variables appears to represent a small transformation. However, as a check of the robustness of the test for returns to teamwork to the value of shift parameter, I also performed the tests after transforming the data by shift parameters of .1 and 10. In the four models estimated with the three shift parameters, the null hypothesis of no productivity advantage for team labor is rejected below the five percent significance level for 10 out of 12 of the cases. For the other two cases, I obtain a p-value of 0.082 on this hypothesis test in the village fixed effects model with a shift parameter equal to 1 (shown in column 4 of Table 4.1) and a p-value of 0.117 in the village fixed effects model with a shift parameter of .1. I conclude that the test for returns to teamwork is quite robust to the choice of shift parameter.

Interestingly, other piece rate labor did not demonstrate an incentive effect. Its coefficient in all four models is smaller than the coefficient on other hired labor, but this difference is not significant in any model except for the one using village fixed effects. As a precaution, I tested for a productivity advantage of piece rate team labor over other hired labor and reject equality of these coefficients for the IV estimators. In the fixed effects regression, other hired labor has a larger coefficient than piece rate team labor, but again the difference is not significant. It is worth noting that these results do not support a productivity advantage for household labor relative to (non-piece-rate) hired labor because of moral hazard, as assumed in the model in Chapter 2. The coefficient on household labor hours is not significantly different from the coefficient on other hired labor in any of the models. In a separate regression not shown here with hired labor hours aggregated, household labor was more productive than hired labor (a coefficient of 0.359 versus 0.296, respectively) but the difference was not significant. This could arise even in the presence of moral hazard if hired labor is more prevalent in tasks with a higher return to labor hours. This would be the case if household labor is devoted more heavily to tasks that require greater care and so more labor time, as observed by Eswaran and Kotwal (1985).

These results provide rare evidence of returns to teamwork in agricultural production and they contribute to a small literature that demonstrates productivity gains from team production in general. They also establish a necessary condition for the use of labor exchange for this sample of rice and corn farmers in Indonesia. Moreover, this evidence contradicts the claim made by Eswaran and Kotwal (1986), following the development of their model of the organization of agricultural production, that gains from teamwork are not a relevant justification for the hierarchical employer-employee relationship in agricultural settings:

> Agriculture is one sector for which the explanation of hierarchical employment relationships on the basis of a presumed technological advantage of team production is not compelling. Since the various production activities are necessarily spread out over time, it is possible for individual agents to operate as efficiently as would a team (p. 497).

The results here showing a productivity advantage for piece rate teams over individual piece rate workers refutes this assertion by Eswaran and Kotwal, at least for the Indonesian farms in this sample. However, because I have shown that returns to teamwork are a necessary condition for labor exchange, all labor exchange teams anywhere provide a counterexample to their claim. In the Indonesian sample, these counterexamples arise in many different settings, for production of several crops and for various activities. This suggests that the returns to teamwork in agriculture may be widespread.

Table 4.1: Cobb-Douglas Production Function Estimates of Returns to Teamwork

Dependent Variable:[+] Log Value of Output	Pooled OLS	Pooled IV	Household Random Effects IV	Village Fixed Effects
Non-team piece rate (PR) labor hours[++]	0.091 ***	0.071	0.076	0.064 ***
	(0.024)	(0.149)	(0.135)	(0.020)
Piece rate team labor hours[++]	0.233 ***	0.821 ***	0.799 ***	0.130 ***
	(0.046)	(0.295)	(0.182)	(0.034)
Other hired labor hours[++]	0.154 ***	0.309	0.334 *	0.179 ***
	(0.054)	(0.197)	(0.203)	(0.025)
Household labor hours[++]	0.084 ***	0.621 **	0.594 ***	0.073 ***
	(0.021)	(0.246)	(0.150)	(0.019)
Non-labor cost[++]	0.239 ***	0.087	0.033	0.201 ***
	(0.060)	(0.169)	(0.132)	(0.032)
Area planted	0.179 *	0.030	0.047	0.129 ***
	(0.091)	(0.123)	(0.097)	(0.035)
Value of farm equipment	-0.007	-0.021	-0.015	-0.004 ***
	(0.013)	(0.035)	(0.028)	(0.011)
Technical irrigation dummy	-0.257 *	-0.360	-0.286 *	-0.358 ***
	(0.136)	(0.235)	(0.170)	(0.112)
Simple irrigation dummy	-0.165	-0.056	-0.015	0.009
	(0.185)	(0.257)	(0.182)	(0.101)
Dryland dummy	-0.415 ***	-0.270	-0.326	-0.470 ***
	(0.135)	(0.217)	(0.211)	(0.120)
Household head age	0.288	0.109	0.134	0.202
	(0.176)	(0.275)	(0.203)	(0.132)
Household head education	0.146 **	0.287 **	0.284 ***	0.099 **
	(0.065)	(0.129)	(0.090)	(0.050)
N	1031	1031	1031	1031
R^2	0.378	--	0.220	0.328
p-value: F(19,1001); F(19, 6); Wald chi2(19); F(14, 987)	0.000	0.000	0.000	0.000
Test: Returns to Teamwork				
Test for equality of non-team PR and PR team effects (p-value):	0.014	0.036	0.006	0.082

Table 4.1: (continued)

Marginal products:				
Non-team piece rate labor hours	4.623	8.871	8.742	2.968
	(1.204)	(18.428)	(15.413)	(0.928)
Piece rate team labor hours	40.608	349.421	314.365	20.709
	(7.964)	(125.746)	(71.891)	(5.469)

[+]Parameter estimates for season and province dummies are omitted. All explanatory variables except land are in log form after adding a shift parameter equal to one. Standard errors are in parentheses. Pooled models use Huber/White/sandwich robust standard errors adjusted for clustering. ([++]) Indicates an endogenous variable, instrumented in IV models. The marginal product of the *j*th input on the *k*th plot is calculated as $MP_{jk} = \hat{\beta}_j \hat{Y}_k / L_{jk}$ where $\hat{\beta}_j$ is the parameter estimate representing the output elasticity of the *j*th factor and $\hat{Y}_k$ is predicted value of output. Marginal products are calculated from the means of the data. Standard errors of marginal products are calculated by the delta method. * Significant at 10%; ** Significant at 5%; *** Significant at 1%.

4.4 The Determinants of Participation in Labor Exchange If All Households Are Working Capital Constrained

In this section, I estimate the determinants of the farmer's decision to participate in a labor exchange team assuming that all farmers are working capital constrained. In the next section, I consider alternative divisions of the sample into constrained and unconstrained regimes. The probit models for labor exchange participation are estimated at the plot level for each household by season. Using plot-specific data on labor exchange demand makes it possible to control for technological factors such as plot size and type of irrigation as well as crop choice and plot ownership status. Differentiating labor exchange use by season helps to account for differences in growing conditions and labor market conditions during the agricultural year.

4.4.1 The Choice of Explanatory Variables

I define working capital holdings in each season as the sum of savings and loans outstanding at the beginning of the season plus new loans taken during the season.[57] The theoretical model in Chapter 2 shows that the level of working capital, land endowments and other assets have no effect on the probability of using labor exchange for households that are unconstrained in their access to working capital, but do affect the labor exchange decision in constrained households. These effects differ by mode of production, but a general pattern of effects of these endowments on labor exchange emerged from the model. For farmers with the lowest levels of working capital or land (*laborer-cultivators*

[57] I provide a detailed description of the approach used to construct this measure of working capital in Appendix D.

in the model), these endowments are positively related to demand for labor exchange. As endowments increase, their effect on demand for labor exchange depends on substitutability of team size with land and on supervision costs. Working capital and land endowments are most likely to have a negative effect on demand for labor exchange at moderate to high endowment levels, where the mode of production also includes hiring market labor on farm. It should be possible to identify these effects of working capital endowments on demand for labor exchange in the labor exchange participation decision, which is driven in part by the level of returns to teamwork and the search costs associated with finding labor exchange teammates. Those factors that increase demand for labor exchange also raise the benefits to participation in labor exchange teams, which increases the probability that the household will participate.

Although the effects of working capital and other variables differ by mode of production, I estimate the decision to participate in labor exchange for the entire farming sample rather than by mode of production. The latter approach would involve classifying households according to the four market labor regimes of Table 2.1 and estimating the decision to use labor exchange separately for each one. These market labor regimes correspond to the modes of production described by Roemer (1982) and Eswaran and Kotwal (1986): *laborer-cultivator*, *self-cultivator*, *small capitalist*, and *large capitalist*. This empirical strategy was rejected for several reasons. First, the classification of households into modes of production is sensitive to the reference period. If the length of a time period is taken to be one season, there is sufficient slack in agricultural activities that many households would be classified as simultaneously buying and selling labor.

For the 1691 household observations by season in the farming sample in labor exchange villages, the four market labor regimes contain 21.8, 17.5, 26.9 and 1.9 percent of the observations, respectively.[58] The remaining 31.9 percent of observations are households that both hired and supplied paid market labor during the season. This mode of production, identified in the second row of Table 2.1, was ruled out in the Eswaran and Kotwal (1986) model, but arises in the model in Chapter 2 because of returns to teamwork. However, the model in Chapter 2 rules out the use of labor exchange with this mode of production, so no predictions of a systematic relationship between working capital endowments and labor exchange are possible for this alternative mode of production. Using a shorter reference period, say the duration of a farming activity (e.g., planting, weeding), would reduce the number of households classified as simultaneously buying and selling market labor, but is inconsistent with the model. Another practical consideration for not estimating the labor exchange decision by mode of production is the reduced precision of parameter estimates given the small number of observations that would fall into some modes after dividing the sample by mode of production and, later, by working capital constraint status.

Given these difficulties in classifying households by mode of production, a more robust empirical strategy is to estimate the labor exchange decision for the entire farming sample and account for differences in the effects of key explanatory variables, such as working capital and land endowments, across modes of production by appropriately defining regressors. For example, entering these endowment variables in the model in

[58] These classifications ignore labor exchange and classify households according to demand and supply of household and paid market labor only.

quantiles should approximate the continuum of modes of production that emerge as endowments increase. The data suggest that such a strategy is valid and may identify the pattern of effects of these variables on participation labor exchange described by the model. Table 4.2 presents average working capital endowments and area of owned land by the four market labor regimes from Chapter 2, with a residual category for those simultaneously hiring and selling paid labor. Average working capital holdings and land endowments rise monotonically across the four market labor regimes as predicted by Eswaran and Kotwal (1986). According to the model in Chapter 2, those simultaneously hiring and selling paid labor could have endowments anywhere along this continuum. In this sample endowments for this mode of production are below those of self-cultivators. These results suggest that endowment levels can serve as a reliable proxy for mode of cultivation in estimation of the labor exchange decision.

Non-land assets should have similar effects on labor exchange as working capital to the extent that they represent viable sources of collateral for borrowing. Otherwise, stocks of these assets will have a weak association with the labor exchange decision. I measure the net value of non-land assets as the sum of all non-farm business assets, household assets, livestock, and farm equipment, net of debt used to finance these assets.

Table 4.2: Working Capital and Land Endowments by Market Labor Regime

Market Labor Regime	Mean Working Capital Holdings, Rp. mn.	Mean Land Area Owned, Hectares
Laborer-cultivator	0.018	0.431
Self-cultivator	1.270	1.062
Small capitalist	2.949	1.494
Large capitalist	3.510	1.748
Simultaneously hire/sell paid labor	0.661	0.855

Land endowments are measured by land area owned. In addition to the endowment effect of owned land as a source of collateral for working capital, operated land area affects the level of returns to teamwork and the search costs for finding potential labor exchange teammates through the plot size distribution. If the area of a farmer's plot is a common local plot size, the farmer will have lower search costs for finding labor exchange teammates. Also, farmers with a great deal of other land under cultivation will be less able to devote time to working on other farmer's plots through labor exchange. I capture these effects in a separate specification of the model by replacing land endowments with two variables: the area of the plot in that observation and the area of all other plots planted during the same season. These effects of plot size and size of other plots do not vary systematically by working capital constraint status. The effect of plot size relative to the village distribution of land is also captured by the share of village sample plots within ten percent of the area of the plot for that observation. As this share increases, search costs for labor exchange teammates will decline, increasing the probability that the farmer will join a labor exchange team.[59]

If paid labor markets are subject to transactions costs like those in the model from Chapter 2, the size of the local labor market will affect demand for labor exchange by changing the relative magnitude of search costs for paid and exchange labor. For example, in villages where land is abundant and most households are engaged in farming, search costs for paid labor will be high because few landless households provide a source of hired labor. I use the share of adults in the village that report agricultural laborer as their primary or secondary occupation in the 1998 village census as a proxy measure for the size of the agricultural labor market during the 1998-99 agricultural year. This should be a good measure of the local availability of hired workers because it includes all adults in every household living in the immediate neighborhood or *kampung*. I also use the average village hourly wage for time rate contracts by season to control for local wage rates. The effect of wage rates depends on whether the household is a net buyer or net seller of labor. For net sellers of labor, an increase in the wage rate reduces demand for labor exchange by increasing the opportunity cost of time, but it also raises liquidity. The liquidity effect increases demand for labor exchange as the scale of operation expands. For net buyers of labor, higher wages raise the price of market substitutes for labor exchange, making labor exchange more attractive. In the empirical model, I interact the wage rate with dummy variables for net buyers and net sellers of labor to identify these effects.

[59] The means of these variables in the plot-level data for the farming sample in labor exchange villages are presented in the first column of Table 4.2.

A number of plot-specific characteristics other than area are also included as regressors to control for differences in growing conditions. I include dummy variables for whether the plot has technical irrigation or simple irrigation as possible regressors. The former is a more mechanized system involving water pumps and the later relies on gravity to deliver the water. In the farming sample in labor exchange villages, 11.1 percent of plots planted use technical irrigation and 15.0 percent use a form of simple irrigation. These variables provide a test for whether reliance on labor exchange is inconsistent with advances in agricultural technology. In the case of irrigation, these inconsistencies may arise because use of exchange labor on irrigated plots would require coordination of scheduling of the water delivery and the work team's activities. As a control for another measure of technological advancement, I include indicator variables for the use of high yielding variety (HYV) seeds interacted with crop-specific indicators for rice and corn. Adoption of HYV seeds may have competing effects on the use of labor exchange. It will increase labor demand overall and may increase team labor demand, depending on the technology. However, the use of HYV seeds may also indicate a level of commercialization and access to markets that makes reliance on non-market forms of exchange unnecessary.

I include the number of plantings on the plot during the 1998-99 agricultural year as a measure of demand for team labor arising from the need to complete tasks quickly. However, a negative association between labor exchange use and the number of plantings may arise if labor exchange is more common on crops that are planted less frequently or in areas where the intensity of agricultural activity is low. An indicator for whether the plot is owned captures whether land ownership affects labor exchange use. Ownership could reduce demand for labor exchange by increasing access to capital to finance paid labor. It will also increase the farmer's motivation to invest in the land, which would be important if farming practices by labor exchange teams are more likely to include soil conservation activities.

I include household demographic and education variables as measures of labor demand and managerial ability. As shown in Chapter 2 for self-cultivators using labor exchange, an increase in the number of household members reduces demand for external team labor but also relaxes the time constraint, which has a countervailing effect. For other modes of production, no unambiguous effect of household size on labor exchange can be derived, but it is reasonable to expect that the substitution effect of a larger household labor team will usually outweigh the endowment effect from having more household members. Household head age could be an important determinant of participation in labor exchange teams, but the direction of its effect may not be systematic. As noted in Chapter 1, labor exchange teams are often formed among social equals, and so may be homogenous in age. However, labor exchange teams may still form among both older and younger farmers separately. The average age of these groupings will determine the effect measured in the labor exchange probit regressions. In general, older farmers may be more likely to use labor exchange due to greater experience and familiarity with local operation of the institution. I also include household head education as a control for managerial ability, access to financial markets, and predisposition to non-market reciprocal exchange. I expect managerial ability to reduce supervision costs, possibly more so for paid labor than for exchange labor. If education increases credit market access, it will increase demand for labor exchange on small farms, but may reduce it on larger farms, as shown in Chapter 2. Education may also affect preferences for entering reciprocal exchange relationships, although the sign of this effect depends on the nature of the education in ways that are not discernable in the data.

In estimation, the sample is restricted to farmers in villages with the labor exchange institution (the 1998-99 "labor exchange villages") because only farmers in these villages have the opportunity to participate in labor exchange, as argued in Chapter 3. Therefore, my estimates of the decision to use labor exchange can be interpreted as conditional on the presence of the labor exchange institution in the village. Including farmers in villages without the labor exchange institution in the sample would lead to biased estimates of the effects of explanatory variables on the farmer's labor exchange decision. It would also improperly reduce the fraction of the variance in labor exchange decisions that can be explained because there is likely to be greater heterogeneity in unobservable village and household characteristics across labor exchange and non-labor exchange villages. The interpretation of estimates on this broader sample would also no longer conform to the model in Chapter 2 because the dependent variable would indicate whether a farmer chose to use labor exchange *and* had access to it. This empirical strategy confounds two separate events, a decision by the farmer and a constraint based on access to labor exchange. It is also important to note that restricting estimation to the sample of households in labor exchange villages would lead to selection bias if farmers were able to migrate from non-labor exchange to labor exchange villages in order to take advantage of labor exchange. Most farmers in the sample own at least some of the land that they farm, and land sales transactions are relatively infrequent in the data. This suggests that potential selection bias due to labor-exchange-induced migration is likely to be very small.

4.4.2 The Effect of Working Capital, Land Endowments, and Other Assets

Table 4.3 presents estimates of probit models of the labor exchange participation decision by plot for the entire farming sample from labor exchange villages under the assumption that all farmers are working capital constrained. Farmers used labor exchange on 16.2 percent of plots by season in this sample. These models differ in their treatment of unobserved household effects across plots, but in each model seasonal effects are modeled as fixed because the number of seasons is small (Judge et al., 1985, p. 537). In the first three models of the labor exchange decision, plot observations are pooled across households using partial maximum likelihood probit estimators with different explanatory variables. In Model 1, working capital is included as a continuous regressor and land is entered as total area owned to measure its endowment effect. In Model 2, indicators for quintiles of working capital are used to allow the effect of working capital to vary by levels. Model 3 substitutes plot area and area of other plots operated in the same season for total land area owned. Model 4 is a random effects probit model that accounts for possible correlation of the error term across plots operated by the same household.

If all farmers are working capital constrained, it is not necessary to control for selection on working capital constraint status in estimation. In this case, the likelihood function for the decision to use labor exchange in (4.6) simplifies to a binomial probit, with observations varying by household, $i = 1,..., N$, by plot, $j = 1,..., J$, and by season, $t = 1,..., T$:

$$(4.7) \qquad LLF_{ijt} = L(\beta, \sigma_u \mid y, X) = \prod_{y_{ijt}=1} \Phi(X_{ijt}\beta) \prod_{y_{ijt}=0} \Phi(-X_{ijt}\beta),$$

where Φ is the cumulative standard normal distribution function. Because β and σ_u are not separately identified, I use the common normalization that $\sigma_u = 1$. With seasonal effects fixed, they can be omitted from the remainder of the discussion. A remaining issue is the choice of estimator when there may be multiple plot observations for each household. A tractable approach is the pooled probit model using a partial maximum likelihood estimator (PMLE), as described in Wooldridge (2002, pp. 401-405; 482-483). Let $D(y_j \mid X_j)$ be the distribution of y_j given X_j and let $f_j(y_j \mid X_j; \beta, \gamma, \sigma)$ be the corresponding density for the *j*th plot. The simplification provided by the partial maximum likelihood estimator (PMLE) in this case is that it is not assumed that

$$\prod_{j=1}^{J} D(y_{ij} \mid X_{ij})$$

is a conditional distribution of the complete vector y_i. Although $f_j(y_j \mid X_j; \beta, \gamma, \sigma)$ is the correct density for y_{ij} given X_{ij} for the *j*th plot, the product of these densities may not be the density for the vector y_i given some X. The PMLE maximizes the expected value of the partial log likelihood for each observation *i*

$$L_i(\beta, \gamma, \sigma) = \sum_{j=1}^{J} \log f\left(y_{ij} \mid X_{ij}; \beta, \gamma, \sigma\right)$$

as long as the densities $f_j(y_j \mid X_j; \beta, \gamma, \sigma)$ are correctly specified. The attraction of the pooled PMLE is that it is straightforward to estimate and that the parameter estimates are consistent and asymptotically normal even if the error terms are arbitrarily correlated across plots (Wooldridge, 2002). The random effects probit model in Model 4 is a more efficient estimator if observations within households are correlated.

The selection of explanatory variables in the pooled probit models was constrained by degrees of freedom restrictions imposed by the sample design. The asymptotic distribution of the F statistic for a Wald test of joint significance of regressors has degrees of freedom based on the number of clusters in the sample. This limits the number of explanatory variables that can be included in the model to 22, the number of labor exchange villages in the sample minus one degree of freedom for the constant term. With five province indicators and two season indicators, the maximum number of remaining regressors is 15. As a result, some variables that were not significantly different from zero were dropped from the estimation in each specification. In a few cases, variables that were statistically significant were omitted from the regression in order to meet this degrees-of-freedom restriction. The remaining variables included in the models are quite robust to model specification in Models 1-3. F tests for joint significance of all regressors, presented near the bottom of Table 4.3, yield significance levels below seven percent for Models 1 and 2 and below one percent for Model 3. Korn and Graubard (1990) show that a Bonferroni t statistic has more power than an F-distributed Wald test when the number of explanatory variables approaches the degrees of freedom set by the number of clusters in the sample. The Bonferroni measure rejects the null hypothesis that effects are jointly zero when

$$\max_{i=1,\ldots,k}\left(\left|\hat{\beta}_i / s_i\right|\right) \geq t_d^{\alpha/2k},$$

where s_i is the standard error of $\hat{\beta}_i$ and $t_d^{\alpha/2k}$ is the upper $\alpha/2k$ point of a t distribution with *d* degrees of freedom. The Bonferroni adjusted p-value is defined as

$$p_i^b = \min(1, kp_i),$$

where p_i is the p-value on a t test for the significance of $\hat{\beta}_i$. I present the p-value for the Bonferroni-adjusted t statistics near the bottom of Table 4.3. This test rejects the null hypothesis at p-values below one percent for all three models.

For the pooled probit models, the pseudo-R^2 was .281, .234, and .239 for Models 1-3, respectively. The predicted probability of using labor exchange on a sample plot at the mean of the explanatory variables ranges from .079 to .096 in Models 1-3, while the fraction of plots on which labor exchange is observed is 0.162. In Model 1, 33.7 percent of plots on which labor exchange was used $(y_i = 1)$ were predicted to have labor exchange $\left(\Phi\left(X_i \hat{\beta}\right) > .5\right)$. In Models 2 and 3, the share of labor exchange plots correctly predicted to have labor exchange fell to 22-24 percent. The share of all labor exchange outcomes $(y_i = 1 \text{ or } y_i = 0)$ correctly predicted by each model was roughly 85 percent. These results suggest a reasonable model fit.

In Model 1 in Table 4.3, holdings of working capital have a significant negative effect on the probability of using labor exchange on the given plot.[60] This effect is the average across all modes of production observed in the data. Recall from Chapter 2 that the effect of working capital holdings on demand for labor exchange for working capital constrained households is positive at low levels of working capital, but depends on technology and market factors at higher levels and may be negative there. If the assumption that all of these households are working capital constrained is correct, the negative parameter estimate implies that the effect is indeed negative for households with moderate-to-large endowments of working capital and land and that this effect dominates, on average, the positive relationship between liquidity and labor exchange use among households with lower working capital. The marginal effects and elasticities of

[60] In all models presented here in which province and season indicator variables are used, the omitted province is South Sulawesi and the omitted seasonal indicator is the one for crops grown on an annual basis.

explanatory variables for the models in Table 4.3 are presented in Appendix E, Table E.1. In Model 1, the size of the effect of the working capital endowment on the probability of using labor exchange is small, with an elasticity at the mean of the data of -.065. This minor role for imperfect capital markets may be due to the countervailing effects of working capital on demand for labor exchange at different working capital endowment levels. Also, the estimated effect of working capital on the labor exchange decision of working capital constrained households would be biased downward if some of these households are not constrained. Nonetheless, this small but significant negative effect lends some support to the popular belief in existing literature that the prevalence of labor exchange is negatively associated with liquidity.

A better test of the theory in Chapter 2 can be conducted by allowing the effect of working capital on the labor exchange participation decision to vary by the size of the working capital endowment, as described in Section 4.4.1. Model 2 in Table 4.3 presents estimates of the labor exchange participation decision in which the level of working capital holdings has been replaced with dummy variables indicating the household's season-specific designation in quintiles of working capital endowments generated from all farming households in labor exchange villages across all seasons. In this sample, 42.4 percent of households fall into the first quintile, which includes all those with non-positive holdings of working capital.[61] As a result, there is no second quintile and the third quintile contains less than 20 percent of the observations. The fifth quintile is the

[61] Working capital holdings in the rainy season include net income from all activities in the preceding dry seasons, which leads to negative working capital holdings for some households in the rainy season. See Appendix D for a detailed description of the construction of this measure of working capital. The working

omitted category in estimation. Median holdings of working capital by ascending quintiles are Rp. 0, Rp. 133,333, Rp. 877,003, and Rp. 5 million, respectively. An F test and a Bonferroni adjusted t test on the coefficients on the working capital quintile indicators shows that they have a significant effect on the probability of using labor exchange, with p-values of .063 and .034, respectively.

The parameter estimates for quintiles of working capital strongly support the theoretical predictions from the model. As an example, consider the effect of a change in the quintile of working capital holdings on the probability of using labor exchange for households in Central Java during the rainy season.[62] At the mean value of the other explanatory variables in Central Java during the rainy season, having working capital holdings in the first quintile (effectively zero working capital) makes the probability of using labor exchange 18.2 percent. Having working capital endowments in the third, fourth and fifth quintiles leads to probabilities of using labor exchange of 25.1 percent, 22.7 percent, and 13.6 percent, respectively. This implies that an increase in working capital holdings from the first to the third quintile raises the probability of using labor exchange by 6.9 percent, but that further increases in working capital quintiles starting from the third and fourth quintiles reduce the probability of using labor exchange by 2.4 percent and 9.1 percent, respectively.

These results are consistent with the model of labor exchange in Chapter 2. The model predicts that farmers with the lowest endowments of working capital operate as laborer-

capital variable was left negative for these observations because this reflects an unmeasured ability to borrow or some unreported savings in the dry season.

cultivators and have a positive relationship of working capital endowment levels to demand for labor exchange. As working capital endowments grow and farmers move into the self-cultivator, small-capitalist and large capitalist modes of production, the relationship depends, among other things, on substitutability of team size and labor time for land and on supervision costs. The empirical evidence from Model 2 indicates that the negative effect of working capital holdings on exchange labor demand dominates countervailing effects at high levels of working capital. Just above the median level of working capital holdings, further increases in working capital reduce the probability of joining a labor exchange team. This is the dampening effect of liquidity on labor exchange use that is frequently cited in the sociological literature. However, in this sample that effect only arises in the upper half of the working capital distribution.

Endowments of non-land assets have no effect on the probability of using labor exchange, which suggests that these assets are not a significant source of collateral for borrowing and that they were correctly classified as fixed, rather than working capital.

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[62] The pattern of effects across working capital quintiles is similar in other provinces and other seasons.

Table 4.3: Determinants of Participation in Labor Exchange, Farming Sample

Dependent Variable: Indicator for Labor Exchange Use by Plot, Season	Means	Model			
		(1)	(2)	(3)	(4)
		Pooled Probit: Working capital in levels and land area owned	Pooled Probit: Quintiles of working capital	Pooled Probit: Plot size replaces land area owned	Random Effects Probit
Working capital: credit taken or outstanding plus savings by season, Rp. mn.	2.142 (0.389)	-0.016** (0.007)			
First quintile of working capital	0.422 (0.045)		0.192 (0.163)	0.188 (0.146)	0.137 (0.138)
Third quintile of working capital	0.145 (0.023)		0.428** (0.177)	0.436** (0.163)	0.390*** (0.176)
Fourth quintile of working capital	0.230 (0.023)		0.350** (0.127)	0.362*** (0.117)	0.272** (0.096)
Value of non-land business, household, and farm assets net of credit financing, 1998	6.281 (0.806)	-0.005 (0.007)	-0.001 (0.004)	-0.002 (0.004)	-0.007 (0.005)
Number of household members	4.812 (0.134)	-0.055** (0.026)	-0.082*** (0.027)	-0.081*** (0.027)	-0.049 (0.037)
Number of plantings on this plot, 1998-99	1.914 (0.106)	-0.260*** (0.075)	-0.271*** (0.078)	-0.256*** (0.075)	-0.121** (0.070)
Indicator for simple irrigation	0.150 (0.044)	0.344* (0.198)	0.315* (0.183)	0.414** (0.189)	0.463*** (0.150)
Indicator for plot being owned, not leased	0.821 (0.027)	-0.352** (0.126)	-0.363*** (0.126)	-0.310** (0.122)	-0.276** (0.125)
Indictor for HYV seeds used in corn production	0.058 (0.025)	0.827*** (0.221)	0.603** (0.244)	0.587** (0.278)	0.713*** (0.155)
Land area owned (hectares)	1.236 (0.144)	0.048 (0.048)	0.067 (0.039)		

(continued…)

Table 4.3 (continued)

	Means	Models			
		(1)	(2)	(3)	(4)
Ln of plot area	-0.940 (0.139)			0.185*** (0.063)	0.197*** (0.050)
Area of other plots planted this season by this household (hectares)	0.307 (0.049)			-0.078 (0.067)	
Share of village sample plots within 10% of this plot's area by season	0.118 (0.010)	1.123** (0.503)	0.754 (0.503)	0.757 (0.477)	0.786** (0.370)
Share of adults in village working as an agricultural laborer, 1998 census	0.167 (0.028)		-1.005** (0.432)	-1.176** (0.491)	-1.219** (0.510)
Average village hourly wage for time rate contracts, by season (Rp. '000)	1.360 (0.087)	-0.464 (0.287)			-0.862*** (0.253)
Average village hourly wage × Indicator for net seller of labor	0.609 (0.068)	0.820** (0.292)			0.860*** (0.103)
Average village hourly wage × Indicator for net buyer of labor	0.555 (0.036)	1.144*** (0.302)			1.193*** (0.072)
Household head age (years)	49.007 (0.876)	-0.008* (0.004)	-0.010** (0.004)	-0.009** (0.003)	-0.009* (0.004)
Household head education level (years)	4.745 (0.329)	-0.026 (0.017)	-0.011 (0.015)		
Lampung province indicator	0.258 (0.099)	-1.302*** (0.222)	-1.124*** (0.269)	-1.049*** (0.282)	-0.938*** (0.162)
Central Java province indicator	0.190 (0.087)	-0.493** (0.218)	-0.404* (0.202)	-0.277 (0.219)	-0.157 (0.129)
East Java province indicator	0.135 (0.076)	-1.944*** (0.286)	-1.700*** (0.305)	-1.547*** (0.319)	-1.648*** (0.223)
West Nusa Tenggara province indicator	0.164 (0.079)	-1.016*** (0.267)	-1.029*** (0.240)	-0.998*** (0.286)	-0.835*** (0.132)
North Sulawesi province indicator	0.081 (0.058)	-1.075** (0.446)	-0.718* (0.393)	-0.785* (0.412)	-0.888*** (0.228)

(continued…)

Table 4.3 (continued)

	Means	Models			
		(1)	(2)	(3)	(4)
Rainy season indicator	0.377 (0.026)	0.918*** (0.258)	1.213*** (0.274)	1.189*** (0.262)	0.790*** (0.117)
Dry season indicator for both dry seasons	0.299 (0.029)	0.886*** (0.242)	1.142*** (0.252)	1.121*** (0.243)	0.776*** (0.059)
Constant		-0.212 (0.398)	0.170 (0.324)	0.228 (0.342)	-0.028 (0.063)
Log (partial-)likelihood		-641.59	-683.60	-677.77	-542.47
Observations	2009	2017	2017	2009	2009
Number of households					818
Psuedo-R2		0.2809	0.2338	0.2392	0.3082
p-value: F(21,2); F(21,2); F(21,2); LR chi2(23)		0.0666	0.0570	0.0045	0.0000
Bonferroni model t test (Prob>t):		0.0000	0.0003	0.0016	
Predicted probability at mean of *X*	0.1616	0.0794	0.0962	0.0939	0.0844
Proportion of variance explained by household-level error component, ρ;					0.8195
LR p-value for H_0: $\hat{\rho}=0$					0.000

For the pooled models, standard errors in parentheses are based on the Huber/White/sandwich robust estimator of variance, adjusted for clustering in sample design. The p-values for the test of joint significance of all regressors are presented below the psuedo-R^2 near the bottom of the table. The p-values for Bonferroni-adjusted t statistics for the test of joint significance of all regressors are reported in the next line. For the random effects model, the reported estimates of the slope coefficients and their standard errors were transformed to make them comparable to the estimates for the pooled probit models using the approach described in Arulampalam (1999). The transformation for the slope coefficients, for example, involves multiplying all estimates by $\sqrt{1-\hat{\rho}}$. Asterisks indicating significance levels for the random effects probit refer to results of Wald tests performed prior to transforming the estimates. In all models, South Sulawesi is the omitted province. The omitted season indicator is for annual crops. Marginal effects and elasticities are presented in Appendix E, Table E.1.
* Significant at 10%; ** Significant at 5%; *** Significant at 1%.

In the model of labor exchange in Chapter 2, land endowments relax the working capital constraint in a manner similar to that of working capital. However, in Model 1 total land area owned has a positive effect on the probability of using labor exchange, although the effect is insignificant (p-value = 0.322). This could signify that the effect of land endowments on demand for labor exchange is positive over more of the distribution of farm size. Alternatively, because land area owned is correlated with the size of operated plots (Pearson correlation coefficient = 0.478), this coefficient may pick up effects of operated area on search costs for labor exchange teammates in addition to the endowment effect. In order to rule out multiple interpretations of land area owned, I replaced this variable with the value of land owned in March 1998 in Model 1.[63] In this probit regression, the sign on the coefficient on value of land owned was negative, but insignificant (p-value = 0.198). Moreover, collinearity between the value of land owned and working capital weakened the size and significance of the working capital parameter, providing further evidence that the estimated effect of land value is not reliable.[64]

4.4.3 The Role of Search Costs, Returns to Teamwork, and the Structure of Labor Exchange

As a more direct test of the role of land in affecting returns to teamwork and search costs for labor exchange teammates, I replaced land area owned in Model 1 with the natural logarithm of operated plot area for the observed plot and the size of all other plots operated during the same season. Results of this specification are shown in Model 3.

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[63] In the interest of space, results from this estimation are not shown. They are available from the author upon request.

[64] I also estimated a model in which the value of land owned was replaced with indicators for land value quintiles, in a treatment similar to that of working capital in Model 2. An F-test failed to reject that the land value quintiles have no effect on the probability of using labor exchange (p-value=.237).

The size of the plot has a significant positive effect on participation in labor exchange. Other area under cultivation had the expected negative sign, but was insignificant. The positive effect of plot size may be capturing greater use of exchange labor in more remote villages with larger farms, an indication that thin labor markets increase demand for labor exchange. Although the province dummy variables should remove much of the effect of regional variation in plot sizes, a model with village fixed effects would test this explanation. However, conditioning the fixed effects out of the likelihood function in a probit model is computationally difficult, and leads to inconsistent estimates of the parameters of interest. Moreover, the number of fixed effects to be estimated increases with the number of households. This is what Neyman and Scott (1948) refer to as the "incidental parameters" problem. Chamberlain (1984) shows that it is possible to obtain consistent estimates of the parameters of interest in this setting by estimating a logit model with village fixed effects. I estimated Chamberlain's model for this problem. The logarithm of plot area remained positive and significant (p-value = .012), which eliminates labor market imperfections as the source of the positive plot size effect.[65] An alternative explanation is that returns to teamwork only emerge in larger plots. Plots in this sample are fairly small; median plot size is just 0.41 hectares.

The other land variable that captures search costs for labor exchange teammates is the share of village plots within ten percent of the size of the plot for that observation. This measures the importance of the size of the pool of potential labor exchange teammates in the decision to use labor exchange. Results for Models 1 show that this variable has a positive, significant and reasonably large effect on the probability of using labor

[65] Complete results of this model are available upon request.

exchange. This variable loses significance and the measured effect declines somewhat in Models 2 and 3. Across the three models, the elasticity of the probability of participating in labor exchange with respect to this variable is ranges from .16 to .25 (see Appendix Table E.1). This provides evidence that farmers assemble labor exchange teams that are homogeneous in plot size. It may be that the coordination costs of operating teams with plots of varying size are high or that farmers prefer to avoid making cash side payments to compensate teammates for additional hours worked on the larger farms. The latter motivation is consistent with constraints on liquidity. These results also demonstrate that the coordination between farmers required by the structure of the labor exchange institution creates constraints on their ability to participate.

The effect of wage rates on participation in labor exchange is captured in Model 1 by the village wage rate entered in levels as well as interacted with indicators for whether the household is a net seller or net buyer of labor. Of the 1613 household observations by season in this sample, 735 are net sellers of labor, 633 are net buyers of labor, and the rest are autarkic with respect to the labor market. The effect of wage rates on either net sellers or net buyers of labor in this specification is given by the sum of the coefficients on the wage and the wage interacted with the appropriate indicator. The estimates from Model 1 show that local wage rates have a positive effect on the probability of participating in labor exchange for both net sellers and net buyers of labor, and that this effect is larger for net buyers. The p-value on a Wald test for joint significance of the wage variables is .002. As described in the previous section, an increase in wage rates can have two effects on net sellers of labor. Higher wages can attract more labor supply off-farm in the labor market, at the expense of labor time spent on farm or in labor exchange. A countervailing effect is that more liquidity from higher wages increases demand for labor exchange teams as the farming operation expands. The positive effect of wages for net sellers in Model 1 implies that this liquidity effect dominates the labor supply effect for this sample of farmers. The large positive effect of wages on participation in labor exchange for net buyers of labor is expected, as farmers respond to higher wage bills by shifting to this non-market substitute for team labor. The marginal effect of an increase in wages for net sellers or net buyers of labor is the sum of the marginal effects of the wage and its interaction with the group dummy from Appendix Table E.1: .053 for net sellers and .101 for net buyers. The corresponding elasticities at the mean of the data are .404 and .702, respectively. These results are significant because they demonstrate that farmers are quite responsive to changes in the price of market labor when deciding on their participation in the non-market labor institution. This suggests that labor exchange is a viable substitute for team labor hired in the market in these villages. Moreover, this fairly high degree of price responsiveness suggests that market labor and labor exchange operate side-by-side. If labor exchange teams were most common where paid labor markets were very thin, a change in the wage rate would have no effect on the probability of using labor exchange.

These wage variables were not included as regressors in Models 2 and 3 because of the degrees of freedom limitations set by the number of sample clusters. Instead, the wage variables were replaced in these models with the share of village adults working as agricultural laborers in the 1998 census. The share of village adults working as agricultural laborers has a significant negative effect on the probabality of using labor exchange in both models. This does not necessarily indicate market failure in village labor markets because an increased supply of laborers could reduce wage rates and demand for labor exchange in a market in equilibrium. I investigate this issue further in Model 4.

Plots using simple irrigation are significantly more likely to be included in labor exchange, as are plots of corn planted with HYV seeds. Because these plots are likely to have higher yields, this demonstrates some synergies between output-enhancing investments and labor exchange use. However, other estimates show that technical irrigation has no effect on the use of labor exchange, suggesting that these synergies dissolve for more advanced, mechanized irrigation technologies.

The number of plantings per year has a significant negative effect on the probability of using labor exchange. This contradicts the argument that greater cropping intensity raises demand for sources of team labor by increasing the time pressure on farming activities. Instead, farms that plant more crops in a year may be more commercialized and make greater use of fertilizer, for example, which would reduce demand for labor exchange at higher levels of working capital endowments. Also, plots that are owned by the farmer are significantly less likely to participate in labor exchange. This may reflect the role of owned land as a source of collateral. A more direct effect is that, other things equal, farmers with rented plots have lower current liquidity available for hiring paid laborers because of their rental obligations.

The negative effect of household size on the probability of using labor exchange shows that the substitution effect of household labor for exchange labor is larger than the time endowment effect of additional household members, as expected. Based on the estimated marginal effects of household size from Model 2, the addition of one household member to a two-person household in Central Java with average characteristics for that province reduces the probability of using labor exchange by 6.1 percent in the rainy season. For a three-person household otherwise in the same condition, one additional member reduces the probability of using labor exchange by 2.9 percent.

Household head education level has a negative effect on the probability of participating in labor exchange, although this coefficient is not significant in Models 1 or 2. However, household head age has a negative and significant affect on labor exchange use. Older farmers are less likely to use labor exchange, although the size of this effect is small. Province dummy variables confirm high prevalence of labor exchange use in South Sulawesi and Central Java. Also, t-tests show that labor exchange is used more on seasonal crops than on annual crops, but that the difference in labor exchange prevalence between the rainy season and dry seasons is not significant in Models 1-3.

4.4.4 A Household Random Effects Model of the Decision to Participate in Labor Exchange

In Model 4 in Table 4.3, I use a household random effects probit estimator to account for correlation of observations across households. Guilkey and Murphy (1993) indicate that, although the slope coefficients are consistently estimated by a pooled probit model, inference based on a pooled probit model may be unreliable because the standard errors can be severely biased. The random effects probit model is estimated using numerical integration methods based on Guass-Hermite quadrature similar to those proposed by Butler and Moffitt (1982). A pseudo-R^2 measure was calculated for this model based on a log-likelihood value of zero representing a perfect model fit. Following Judge et al (1985), let L_1 be the value of the log-likelihood for random effects model estimated here, and let L_0 be the value of the log-likelihood of a model estimated with only a constant. A measure of model fit for discrete models is given by $1 - L_1/L_0$, which rescales the value of the model log-likelihood into the unit interval between a model with perfect prediction and the "constant-only" model with zero predictive power. This pseudo-R^2 for the random effects model was .308. The same information on L_1 and L_0 can be used to construct the likelihood ratio test of the null hypothesis that the slope coefficients are jointly zero. This null hypothesis is rejected with p-value .000, as shown in Table 4.3. The estimated proportion of total variance contributed by the household-level variance component is $\hat{\rho}$=.827. A likelihood ratio test rejects that $\hat{\rho}$=0 with a p-value of .000, which indicates that the random effects probit estimator is preferred to the pooled probit estimator.

The results for Model 4 are broadly consistent with those presented for Models 1-3. Random effects estimates for the value of non-land assets, number of plantings, use of simple irrigation, plot ownership, use of high-yielding-variety seeds for corn, plot area, and household head age are similar to estimates from the pooled probit models.

In Model 4, quintiles of working capital have a significant effect on the probability of using labor exchange. The p-values for a χ^2-distributed Wald test and a Bonferroni t test of the joint significance of the indicators for working capital quintiles are .024 and .020, respectively. The pattern of effects of working capital on participation in labor exchange is similar to the results from the pooled probit estimators in Models 2 and 3. Working capital has a positive effect on labor exchange use at low levels of working capital, and a negative effect at higher levels of working capital. Repeating the example applied to Model 2 for households in Central Java during the rainy season, moving from the first to the third quintile of working capital holdings in Model 4 leads to a 7.7 percent increase in the probability of using labor exchange, but similar moves starting from the third and fourth working capital quintiles are associated with declines in the probability of using labor exchange of 3.8 and 7.5 percent, respectively.

A notable result from Model 4 is that the share of adults in the village working as an agricultural laborer in the 1998 census continues to have a negative, significant effect on labor exchange use even after controlling for the local wage rate. This indicates that the effect of a larger supply of workers in the labor market in reducing reliance on labor exchange does not operate through lower wages for paid labor. Instead, a larger pool of paid laborers must lead to declining search costs for paid labor transactions.[66] This result

[66] Another possible interpretation of this effect is that an increase in the village share of adults working as laborers lowers a given households' probability of participating in labor exchange because it reduces the size of the pool of potential labor exchange teammates. However, the average share of adults working as agricultural laborers in the labor exchange villages is only 16.7 percent and the 75th percentile is 23.4 percent. It is unlikely at these levels that incremental increases in labor force participation would crowd out labor exchange.

provides evidence of transactions costs to hiring paid labor in these villages and shows that these transactions costs have a statistically significant effect on a farmer's probability of using labor exchange.

The role of wages is somewhat different here than in Model 1, but remains consistent with the predictions of the analysis in Chapter 2. Although net buyers of labor continue to increase their probability of using labor exchange as wages increase (elasticity of .333, see Table E.1), there is no effect of wages on labor exchange use for net sellers of labor (elasticity of -.002). According to these estimates for net sellers of labor, the liquidity effect of higher wages, which increases labor exchange demand through a larger scale of operation, is completely offset by the labor supply effect that pulls household labor time away from the farm and into the market.

In this specification of the model, the negative effect of household size on the probability of using labor exchange is no longer significant (p-value .176), as it was in the pooled probit models. This weakens the argument that returns to team size or number of people working on the farm is an important determinant of the decision to use labor exchange. Although the significance of $\hat{\rho}$ suggests that this random effects specification with a household-level variance component is more appropriate for these data, it is more difficult to estimate the slope coefficient and standard error on variables, such as household size, that are constant within household-level observations in the random effects model. Parameters on these variables were more likely to shift with changes in model specification such as changes in included explanatory variables or points of quadrature in the numerical integration. Therefore, I would not completely disregard the results of the pooled probit models for household size, despite the outcome of the test of model specification.

4.5 The Determinants of Participation in Labor Exchange If Only Some Households are Working Capital Constrained

Estimates of the determinants of participation in agricultural labor exchange in the previous section were obtained under the assumption that all households in the farming sample in labor exchange villages were working capital constrained in all seasons in 1998-99. These estimates provided considerable support for the model of labor exchange developed in Chapter 2. A major validation of the model concerned the pattern of the effects of working capital on participation in labor exchange at various levels of working capital holdings. Several other variables reflecting search costs in the labor market, working capital constraints, and the structure of labor exchange arrangements also behaved as predicted by the model. However, the effects of land endowments did not support the model and results on the role of household size were inconclusive. These shortcomings may be due to misclassification of households as working capital constrained. If some farming households in labor exchange villages were unconstrained in their access to working capital during part or all of the 1998-99 agricultural year, estimates of the determinants of participation in labor exchange are biased. Thus, even where the sign and significance of the slope estimates support the general conclusions of the model, the size of the true effects may be different. A more careful examination of which households are likely to be working capital constrained in each season should provide more accurate estimates of labor exchange determinants and can provide the basis for tests of the robustness of measured effects to model specification.

In this section, I estimate the switching regression model for a farmer's decision to use labor exchange from (4.2) and (4.3) subject to an unobserved working capital constraint. I develop an assignment rule to divide the sample into working-capital-constrained and -unconstrained households in each season based on predicted working capital holdings using the methodology described in Section 4.2. Based on this division of the sample, I estimate the likelihood function in (4.6) for the decision to participate in labor exchange subject to possible working capital constraints. Under the assignment rule, constrained households in each season are those with no savings, borrowing or lending. Results based on this assignment rule are presented in Model 5 in Table 4.4. In order to test the robustness of the results to the choice of assignment rule, I estimate (4.6) again under an alternative assignment rule with a more relaxed working capital constraint. Under the alternative assignment rule, households with intermediate levels of working capital holdings (those in the third working capital quintile) are moved from the unconstrained group to the constrained group based on the original assignment rule. Estimates based on this alternative assignment rule are presented in Model 6 in Table 4.4.

In order to assist in the estimation of the likelihood function, I first estimate probit models for the decision to use labor exchange separately for the two sub-samples of households predicted to be working-capital-constrained or -unconstrained in each model, with a Heckman correction for selection into the relevant sub-sample. These two-step estimators provide consistent estimates of β_1 and β_2 and two separate consistent estimates of γ from (4.6) for each model. After arbitrarily selecting the estimate of γ from the probit with sample selection that includes β_1, I used these estimates of β_1, β_2, and γ as starting values for maximization of the likelihood function in (4.6). The first panel of Table 4.4 presents estimates of γ, the determinants of the probability of being working capital constrained, for Models 5 and 6 and the second panel presents the corresponding estimates of β_1 and β_2, the determinants of participation in labor exchange subject to being working capital constrained or unconstrained, respectively. Both Models 5 and 6 are pooled models that do not allow for correlation in the error terms across plot and season observations within a household.

4.5.1 The Determinants of the Probability of Being Working Capital Constrained

The probability that a household is working capital constrained in a particular season is a function of beginning-of-period holdings of land; farm equipment and livestock; and business and household assets net of outstanding credit taken to finance the purchase of each type of asset. Most of these are illiquid assets. They affect working capital holdings through their ability to serve as collateral for loans. Land is the most common asset used as collateral, and so should be closely associated with working capital. Farm assets may also substantially reduce the probability of being working capital constrained because they include livestock, which are more liquid than the other assets.

Access to credit is affected in part by the size of the credit market. The share of households in the village using credit is used as a proxy for the size of this market. I expect that the explicit and implicit cost of credit will be declining in market size. As a measure of explicit cost of credit and returns to savings, the average village interest rate is included with a quadratic term. I include a plot-level indicator for whether high yielding variety seeds are used, to indicate relatively commercialized farming. The age and education of the household head are included to control for life-cycle effects on savings and managerial ability. The natural logarithm of the number of household members is used to account for the scale of household consumption expenditure. A variable that indicates if the household head has a white-collar occupation accounts for whether professionals have better access to credit markets. The expected sign of the effect of the value of assets, use of high yielding variety seeds, and white-collar occupation is negative and the expected sign of the other household characteristics is positive. Province and season indicator variables are also included to control for unobserved fixed regional and seasonal differences in the size of working capital holdings.

In Model 5, the value of land owned and of farm asset holdings reduces the probability of being working capital constrained, as expected. In order to interpret the magnitude of these effects, marginal effects from the likelihood function in (4.6) must be calculated. The marginal effect of an explanatory variable on any of the joint, conditional and marginal outcome probabilities may be of interest. For now, I consider the effect of an incremental change in a continuous explanatory variable δ_j from X_1, X_2, or W on the marginal probability of being working capital constrained,

$$\frac{\partial \Pr\left(k_i = 1 \mid X, W\right)}{\partial \delta_j}. \tag{4.8}$$

I derive the analytical expression for these marginal effects in Appendix F, relying on the similarity of the likelihood function in (4.6) to the bivariate probit and using results from Christofides, Stengos, and Swidinsky (1997) and Christofides, Hardin, and Stengos, (2000).

At the mean of the data, the marginal effects of land owned and farm asset holdings on the probability of being working capital constrained are -.001 and -.015, respectively.[67] These figures imply that a one-standard-deviation increase in holdings of these assets reduce the marginal probability of being working capital constrained by 4.9 percent and 5.8 percent, respectively. Although the effect of farm assets is small, its significance probably reflects the ease of converting livestock into cash.[68]

Also in Model 5, households in villages with larger credit markets are significantly less likely to be working capital constrained. This does not necessarily indicate the presence of credit market failures. The result could reflect greater credit supply in a credit market

[67] In calculating the marginal effect of farm asset holdings on the probability of being working capital constrained, I assumed that the effect of farm assets in the labor exchange equation is identical to the effect of all non-land assets, a more aggregated variable.

in equilibrium, although it is also consistent with lower transaction costs of receiving loans in imperfect credit markets. The interest rate does not affect the probability of being working capital constrained. This may be due to the competing role the interest rate plays in savings and credit decisions. This result would also obtain if there are fixed transactions costs to participation in rural financial markets.

Although the effect is not significant, use of high yielding variety seeds reduces the probability of being constrained as expected. This may arise because the corresponding increase in yields leads to greater savings or to increased demand for complementary inputs like fertilizer. Household head education significantly reduces the probability of being constrained, as does the household head having a professional occupation. Either education and white-collar job status are associated with lower risk by lenders or they reduce transactions costs for obtaining loans.

At the mean of the data, the predicted marginal probability of being working capital constrained according to the assignment rule in Model 5 is .376. This closely predicts the observed share of constrained households under this assignment rule, which is .397.

Estimation of the switching regression in (4.6) is severely constrained by the degrees of freedom restrictions from the asymptotic theory for the model F test. For this likelihood function, the degrees of freedom restriction is violated if the total number of regressors in X_1, X_2 and W is greater than 23, the number of clusters in the sample. I discussed the

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[68] Data on borrowing in the 1998-99 PATANAS survey show no use of livestock as a form of collateral for loans.

implications of this restriction in Section 4.4.2 for the estimates of the labor exchange decision estimated on the full sample under the assumption that all households are working capital constrained. For the models presented in Table 4.3 in that section, the selection of included regressors was adapted to make sure this restriction was not violated. For estimation of the full likelihood function in (4.6) in which only some households are classified as working capital constrained, meeting this restriction leads to a severe reduction in the number of included regressors. In the estimates for Model 5 in Table 4.4, this degrees of freedom restriction was violated. In general, this leads to biased estimates of the standard errors and renders the model F test that all regressors are jointly zero invalid. In practice, it is not known whether t statistics for significance of individual regressors and F tests based on a small number of regressors will be severely affected.

One alternative approach could be to limit the size of the regressor matrices to meet the restriction. The effect of this restriction for estimation of the full likelihood function is so severe as to render the results meaningless. However, because this restriction is fixed by sample design and does not change with the order of the model being estimated, another alternative is to derive estimates of the parameters for (4.6) by estimating pieces of the likelihood function, one at a time. For example, I could estimate the probability of using labor exchange conditional on being working capital constrained, which would eliminate β_2 from the estimation. Estimates of β_2 could then be obtained by estimating the probability of using labor exchange conditional on being unconstrained in working capital. The corresponding likelihood functions are

$$LLF_i = L\left(\beta_1, \gamma, \sigma_{1u} \mid y, k, X_1, W\right) = \prod_{\substack{y_i=1\\k_i=1}} \Phi_2\left(X_{1i}\beta_1, W_i\gamma, \rho_{1u}\right) \cdot \prod_{\substack{y_i=0\\k_i=1}} \Phi_2\left(-X_{1i}\beta_1, W_i\gamma, -\rho_{1u}\right) \cdot \prod_{k_i=0} \Phi\left(-W_i\gamma\right), \tag{4.9.a}$$

and

$$LLF_i = L\left(\beta_2, \gamma, \sigma_{2u} \mid y, k, X_2, W\right) = \prod_{\substack{y_i=1\\k_i=0}} \Phi_2\left(X_{2i}\beta_2, -W_i\gamma, -\rho_{2u}\right) \cdot \prod_{\substack{y_i=0\\k_i=0}} \Phi_2\left(-X_{2i}\beta_2, -W_i\gamma, \rho_{2u}\right) \cdot \prod_{k_i=1} \Phi\left(W_i\gamma\right). \tag{4.9.b}$$

An early application to estimating likelihood functions of this form is provided in van de Ven and van Praag (1981). Of course, estimating the parameters of the model in (4.6) in this way results in a loss of efficiency. The parameter estimates would be consistent if the degrees of freedom saved by estimating the likelihood function in parts in this way is sufficient that the full X_1, X_2, and W matrices can be included in the estimation. However, if significant regressors must be excluded in order to meet the degrees of freedom restriction when estimating (4.9.a) or (4.9.b), the parameter estimates for the remaining variables will be inconsistent due to omitted variable bias. Thus, there is a tradeoff between bias in the regressors when estimating partial models versus bias in the standard errors for the full model. There is no easy way to assess the relative implications of these sources of bias. For comparison, I have estimated equations (4.9.a) and (4.9.b) for Model 5, with some regressors excluded in order to keep the total number of parameters to be estimated, including the constant term, to 23. Results of these estimates are provided in Appendix Table G.1.

The first panel of Table G.1 presents the two estimates of γ from (4.9.a) and (4.9.b). In many respects, these results are encouraging. They provide broad support for the model of labor exchange under working capital constraints. The signs of all of the coefficients in γ are the same as in the full model in (4.6). Moreover, the Wald test for joint significance of the explanatory variables has a p-value less than .0001 for both estimates. Support for the estimates of γ from the full model of (4.6) in Table 4.4 is mixed. Estimates of some parameters in γ from Table G.1 are close in size to their counterparts in Table 4.4, but many are not. These differences may arise because of changes in the specification of some variables that were required to meet the degrees of freedom restriction. These differences may also be due to omitted variable bias caused by excluding significant variables such as the indicator for plot ownership. The significance of estimates for farm assets, share of village households using credit, and white-collar household head occupation are maintained in Table G.1. Interest rates and household size become significant in Table G.1, but only at the 10 percent level. The greatest cause for concern is that land assets are no longer significant here, despite having a p-value of .038 in Model 5 from Table 4.4.[69] In summary, these results provide additional support for the overall model of labor exchange under working capital constraints, but they suggest some caution in interpreting significance levels of estimates based on the full model in (4.6).

[69] I compare results for estimates of β_1 and β_2 below, after reviewing those results from Table 4.4.

Before analyzing the estimates of β_1 and β_2 for Model 5, I consider the estimates of γ from Model 6, in which the assignment rule for working capital constraint status is changed to broaden the working capital constrained regime to include households with intermediate levels of working capital holdings. Under the new assignment rule for Model 6, households in the third working capital quintile were added to the existing cohort of working capital constrained households identified by the assignment rule for Model 5. Recall that in Model 5 households with non-positive savings and credit outstanding in the current season were classified as working capital constrained. This included all households in the first two working capital quintiles. To this group was added any household in the other quintiles that lent money during the season. This relaxation of the working capital constraint threshold in Model 6 is warranted because the threshold in Model 5 is conservative and may have led to many constrained households being classified as unconstrained. Results from Model 6 provide an informal test of the robustness of the results from Model 5 to the working capital constraint classification.

The estimates of γ from Model 6 are broadly consistent with those from Model 5. Excluding province and season indicator variables, only the estimate for household head age changes sign, and this estimate is insignificant in both models. Both the value of land owned and the value of farm assets reduce the probability of being working capital constrained, but the magnitude of the effect is larger in Model 6. At the mean of the data, a one-standard-deviation increase in land assets and farm assets leads to reductions in the probability of being working capital constrained of 12.9 percent and 8.3 percent, respectively. The effect of an increase in the village share of households using credit is also much larger under the new assignment rule. The effect of the interest rate on the probability of being working capital constrained is now negative and significant at the five percent level. This suggests that this price dominates in the savings decision, since its sign should have the opposite effect on credit use. That the effect of higher interest rates dominates in the savings decision rather than the credit decision is somewhat surprising because most households in the sample do not save assets in a form that is directly affected by interest rates (e.g., interest-bearing savings accounts).

The logarithm of the number of household members also has a significant negative effect on the probability of being working capital constrained in Model 6. It may be that the households with moderate working capital holdings that are included in the constrained group under the new assignment rule are better able to take advantage of the additional earning potential represented by an increase in household size. As in Model 5, household head education and white-collar occupation have significant negative effects on the probability of being working capital constrained, but the size of the effect of education is much larger than before. As with household size, there may be some synergies between education and the level of working capital holdings that enable those with some liquidity to take greater advantage of their education.

4.5.2 Determinants of Participation in Labor Exchange by Working Capital Constrained and Unconstrained Households

The second panel of Table 4.4 presents the determinants of the decision to use labor exchange on the observed plot for constrained and unconstrained households under the two working capital constraint assignment rules in Models 5 and 6. These results lend considerable support to the model of labor exchange presented in Chapter 2. The estimates yield mixed evidence on the appropriateness of the method of sample separation used here. By some measures, both assignment rules classify too many working capital constrained households as unconstrained. As a result, most of the estimated effects of the determinants of labor exchange participation do not differ significantly between the constrained and unconstrained regimes. Pair-wise Wald tests of equality of coefficients for each explanatory variable across the two regimes $\left(H_0 : \beta_{1j} = \beta_{2j} \; \forall \; j = 1,...,k\right)$ failed to reject that the coefficients were equal for each variable in Model 5 except the wage level and some of the province dummies. In Model 6, the same tests failed to reject the equality of the coefficients across regimes for all variables except area of other plots planted this season, household head age, and some province dummies.

The estimated correlation coefficient between the error terms of the working capital constraint equation and the labor exchange participation equation for constrained (unconstrained) households, $\rho_{1u}\left(\rho_{2u}\right)$, is positive (negative) in both models. In Model 5, ρ_{1u} is just insignificant and ρ_{2u} is just significant at the ten percent level. In Model 6, ρ_{1u}, is significant at the ten percent level and ρ_{2u} is significant at the one percent level.

Although these significance levels are weak, they generally support estimating the labor exchange participation decision in this switching regression framework rather than as a univariate probit independent of working capital constraint status. Moreover, the signs of the correlation coefficients indicate that unobserved factors that contribute to the probability of being working capital constrained are positively associated with using labor exchange in the working capital constrained group and negatively associated with using labor exchange for the unconstrained group.[70] This provides new evidence on the relationship between working capital constraints and labor exchange participation. Unobserved factors lead to a positive relationship between the probability of being constrained and using labor exchange for those with zero or low working capital holdings and a negative relationship for those with relatively high working capital. Because this relationship is driven by unobservable factors, it does not contradict the earlier result that an increase in working capital holdings has an inverted U-shaped relationship to the probability of using labor exchange. However, this new evidence suggests a more complex relationship between the level of working capital endowments and the probability of using labor exchange.

Despite the mixed support for the chosen sample separation, the significance of individual coefficients varies across regimes in a manner consistent with the model of labor exchange for some variables, though not for others. I review these results presently. The model in Chapter 2 showed that holdings of working capital should have no effect on the decision to use labor exchange for unconstrained households. This result

[70] Wald tests of equality of the correlation coefficients $\left(H_0 : \rho_{1u} = \rho_{2u}\right)$ rejected the null hypothesis in

is not supported in Table 4.4, where working capital holdings are negatively associated with the probability of using labor exchange, with a higher significance level in Model 6 where the unconstrained group has higher average working capital holdings. These results are consistent with the estimates from Table 4.3 in which the entire sample was treated as working capital constrained. In Models 2-4 in Table 4.3, the effect of working capital holdings on labor exchange use was negative starting with the third working capital quintile. Since the coefficient in Table 4.4 measures the average effect of working capital for quintiles 3-5 in Model 5 and quintiles 4-5 in Model 6, this outcome is not surprising. Because this pattern of effects in Models 2-4 accords so closely with the predictions of the analytical model for working capital constrained households, I interpret these results as evidence in favor of the entire sample being working capital constrained.[71]

A difficulty presented by using zero working capital holdings as the threshold for the assignment rule of working capital constraint status in Model 5 is that the level of working capital cannot meaningfully be included as a regressor for constrained households. This shortcoming is also present in Model 6, where most households have no working capital. As a result, I did not include the working capital variable in either specification for constrained households.

As in the models in which all households were treated as working capital constrained, the value of non-land assets does not have a significant effect on the decision to use labor

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Model 5 (p-value=.001) and Model 6 (p-value=.000).

exchange for either constrained or unconstrained households in either model in Table 4.4. However, in an alternative specification of the model described below in which land area owned replaced the logarithm of plot area and area of other plots planted this season, non-land assets had a weakly significant (p-value=.087) negative effect on the probability of using labor exchange for working capital constrained households and an insignificant effect for unconstrained households. This pattern of effects is consistent with the labor exchange model in Chapter 2. If non-land assets can act as collateral in the credit market, then the liquidity effect of these assets on labor exchange use for working capital constrained households will change from positive to negative as liquidity increases and may be negative on average.

The model also predicts that land endowments will have no effect on labor exchange use for unconstrained households, but will affect the decision to use labor exchange for constrained households. Land area owned was not included in the preferred model specifications in Table 4.4 so that the logarithm of plot size and area of other plots cultivated could be included as regressors without facing severe multicollinearity. Separate regressions were estimated to test for the effect of land endowments, in which land area owned replaced plot size and area of other plots cultivated. The parameter estimates and standard errors for the land area owned variable from these regressions are reported at the bottom of Table 4.4.[72] In both Models 5 and 6, land area owned is positive and significant below the five percent level for the working capital constrained cohort and has no significant effect in the unconstrained cohort. A Wald test rejected

[71] I attempted to estimate the model again under the assignment rule that all households except those in the highest working capital quintile are working capital constrained, but this model did not converge.

equality of the coefficient for land area owned in the constrained and unconstrained cohorts in Models 5 and 6 (p-value = .007 and .028, respectively). One interpretation of the positive sign of this coefficient for the constrained sub-sample is that this group must contain many households in the labor-cultivator mode of production, where working capital and land endowments have an unambiguous positive effect on exchange labor demand. Alternatively, if many farmers are operating under other modes of cultivation, the positive coefficient implies that the effect of increasing demand for team labor arising from expanding land holdings exceeds the benefits of increased access to market labor arising from improved access to credit, which would reduce the probability of using labor exchange.

The effects of household size provide further support for the model in Chapter 2 and for the sample separation used here. An increase in household size significantly reduces the probability of using labor exchange for working capital constrained households in Models 5 and 6 (p-value = .055 and .052, respectively), but not for unconstrained households. Demand for labor exchange is not sensitive to household size for unconstrained households operating in modes of production that include labor market participation due to separability of production and consumption decisions. For self-cultivators in unconstrained households, expansions of land area operated attenuate the effects of increases in household size on demand for labor exchange. However, in working capital constrained households, increases in household size reduce the probability of using labor exchange if the substitution effect of household labor for exchange labor dominates the time endowment effect, as expected.

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[72] Complete results for the model specification including land area owned are available upon request.

The effects of use of simple irrigation, high-yielding variety seeds, and the share of village plots within ten percent of the area of the observed plot are not expected to differ depending on whether the household is working capital constrained. Indeed, these regressors mostly show the same pattern of effects as when the regressions were estimated on the whole sample (see Table 4.3), demonstrating the robustness of these effects across various model specifications.

The area of the cultivated plot is positively associated with demand for labor exchange for both constrained and unconstrained households, as in the estimates for the full sample from Table 4.3. However, the area of other plots cultivated this season by the same household had no effect on the labor exchange decision when all households were treated as constrained in Table 4.3, but has a significant negative effect for the unconstrained group in Table 4.4. Apparently, households that are not working capital constrained and are cultivating other plots are less likely to use labor exchange on a given plot, probably because labor exchange requires too much household labor time. One explanation for why only unconstrained households behave in this manner is that their greater access to liquidity makes them more productive and raises their opportunity cost of time spent in labor exchange relative to that of constrained households.

An increase in the wage rate raises the probability of participating in labor exchange for net buyers and net sellers of labor in both the constrained and unconstrained sub-samples. This is the same effect seen when the entire sample was treated as constrained in Table

4.3. However, for the constrained group these effects are larger than for the unconstrained group or for the full sample, particularly in Model 5. The substitution of exchange labor for paid market labor is more sensitive to the price of paid labor for those who are more liquidity constrained.

Finally, I return to the estimates of the labor exchange switching regression obtained through estimation of the likelihood function in parts in order to satisfy the degrees of freedom restriction imposed by clustered sampling (see Appendix G). The number of explanatory variables in the labor exchange participation equation was reduced in order to meet the restriction. Results from these estimates are similar for the working capital variable (for unconstrained households), for the value of non-land assets, and for the wage variables. However, for working capital constrained households, the effects of household size, simple irrigation, and share of village plots of similar size disappear in these estimates. It is not possible to determine whether these changes in results are due to biased standard errors in the complete model estimates in Table 4.4 or to omitted variable bias in the restricted model estimates in Appendix Table G.1.

In summary, this attempt to divide the sample into working capital constrained and unconstrained cohorts based on the level of working capital holdings has mixed effects on the ability of the estimates to satisfy the predictions of the analytical model in Chapter 2. The effects of working capital on labor exchange use were better explained when all households were treated as constrained. The effect of non-land assets appeared to be more consistent with the model for one specification in which the sample was divided by working capital holdings. Land assets and household size had the expected effects only in the switching regression model. Also, the estimates of the switching regression model were robust to the alternative division of the sample considered here. Overall, applying the additional structure to the model using the switching regression approach provided important additional insights into determinants of participation in labor exchange in the presence of working capital constraints. However, it is not possible to conclude, based on the models considered so far, whether it is more accurate to classify only the households with low working capital holdings or all households in the sample as working capital constrained.

Table 4.4: Switching Regression Estimates of Probability of Participating in Labor Exchange Subject to a Working Capital Constraint

Estimates of γ :	Model	
Determinants of the Probability of Being Working Capital Constrained	(5)	(6)
Assignment rule for working capital constrained households:	**No borrowing, savings, or lending**	**Belong to first three quintiles of working capital holdings with no lending**
Value of land owned net of outstanding land debt, 1998, Rp. mn	-0.003**	-0.007***
	(0.001)	(0.002)
Value of non-farm business, household assets net of outstanding related debt, 1998, Rp. mn	-0.002	-0.006
	(0.003)	(0.004)
Value of livestock and farm equipment net of outstanding farm debt, 1998, Rp. mn	-0.057***	-0.075***
	(0.016)	(0.012)
Share of village households using credit	-1.724***	-2.290***
	(0.521)	(0.292)
Village average interest rate	-0.010	-0.010**
	(0.009)	(0.005)
Village average interest rate squared	0.000	0.000
	(0.000)	(0.000)
Indicator for use of HYV seeds	-0.119	-0.063
	(0.154)	(0.114)
Ln of number of household members	-0.155	-0.243*
	(0.111)	(0.130)
Household head age (years)	0.002	-0.002
	(0.002)	(0.002)
Household head education (years)	-0.027**	-0.050***
	(0.013)	(0.014)
Indicator for white collar household head occupation	-0.851**	-0.797***
	(0.343)	(0.282)
Lampung province indicator	1.383***	1.424***
	(0.391)	(0.201)
Central Java province indicator	0.192	0.554***
	(0.329)	(0.152)
East Java province indicator	0.629*	0.704***
	(0.374)	(0.220)
West Nusa Tenggara province indicator	0.574	0.952***
	(0.423)	(0.174)
North Sulawesi province indicator	0.541**	0.802***
	(0.273)	(0.206)
Rainy season indicator	0.196	-0.128
	(0.127)	(0.127)
Dry season indicator for both dry seasons	0.567***	0.435***
	(0.110)	(0.089)
Constant	-0.104	0.991***
	(0.365)	(0.248)

(continued…)

Table 4.4: (continued)

Estimates of β_1, β_2: **Determinants of the Probability of Using Labor Exchange on this Plot**	Working Capital Constrained Model		Working Capital Unconstrained Model	
	(5)	(6)	(5)	(6)
Assignment rule for working capital constrained households:	**No borrow-ing, savings, or lending**	**Belong to first three quintiles of working capital holdings with no lending**	**No borrow-ing, savings, or lending**	**Belong to first three quintiles of working capital holdings with no lending**
Working capital: credit taken or out-standing plus savings, Rp. mn.			-0.013* (0.008)	-0.014** (0.007)
Non-land business, household, farm assets net of credit financing, 1998, Rp. mn	-0.009 (0.008)	-0.010 (0.010)	-0.003 (0.005)	-0.001 (0.004)
Number of household members	-0.064* (0.034)	-0.061* (0.031)	-0.022 (0.037)	-0.018 (0.039)
Indicator for simple irrigation	0.719*** (0.225)	0.525** (0.242)	0.501* (0.287)	0.518** (0.246)
Indicator for plot being owned, not leased	-0.335** (0.141)	-0.279** (0.132)	-0.317** (0.127)	-0.419*** (0.127)
Indicator that corn is at least half of the value of production on this plot	0.312 (0.314)	0.146 (0.258)	0.155 (0.174)	0.333** (0.161)
Indictor for HYV seeds used in corn production	0.817 (0.623)	0.545 (0.602)	0.741*** (0.189)	0.869*** (0.196)
Ln of plot area	0.163* (0.090)	0.171** (0.082)	0.179** (0.072)	0.149** (0.074)
Area of other plots planted this season by this household	-0.037 (0.161)	-0.017 (0.116)	-0.245** (0.116)	-0.345*** (0.123)
Share of village sample plots within 10% of this plot's area, by season	1.465** (0.664)	1.532*** (0.514)	1.252* (0.644)	1.217* (0.726)
Average village hourly wage for time rate contracts, by season (Rp. '000)	-0.027 (0.376)	-0.579 (0.435)	-0.828*** (0.319)	-0.697** (0.336)
Average village hourly wage × Indicator for net seller of labor	0.869*** (0.322)	0.936*** (0.280)	0.916*** (0.320)	0.761** (0.375)
Average village hourly wage × Indicator for net buyer of labor	1.048*** (0.322)	1.212*** (0.312)	1.353*** (0.365)	1.254*** (0.392)
Household head age (years)	-0.009 (0.007)	-0.013** (0.006)	-0.007 (0.005)	0.000 (0.005)
Household head education level (years)	0.004 (0.023)	-0.025 (0.021)	-0.031 (0.020)	-0.011 (0.023)
Lampung province indicator	-0.619 (0.396)	-0.740** (0.342)	-1.314*** (0.213)	-1.261*** (0.210)

(continued…)

Table 4.4: (continued)

Estimates of β_1, β_2: **Determinants of the Probability of Using Labor Exchange on this Plot**	Working Capital Constrained		Working Capital Unconstrained	
	Model		Model	
	(5)	(6)	(5)	(6)
Assignment rule for working capital constrained households:	**No borrow-ing, savings, or lending**	**Belong to first three quintiles of working capital holdings with no lending**	**No borrow-ing, savings, or lending**	**Belong to first three quintiles of working capital holdings with no lending**
Central Java province indicator	0.183 (0.245)	0.042 (0.257)	-0.440 (0.303)	-0.499* (0.271)
East Java province indicator	-1.286** (0.610)	-1.469*** (0.562)	-2.022*** (0.463)	-1.970*** (0.412)
West Nusa Tenggara province indicator	-0.457 (0.439)	-0.291 (0.406)	-0.755* (0.426)	-1.041*** (0.337)
North Sulawesi province indicator	-0.842 (0.575)	-0.397 (0.553)	-1.183** (0.486)	-1.566*** (0.434)
Constant	-1.589** (0.631)	-0.457 (0.678)	-0.045 (0.431)	-0.564 (0.400)
Correlation coefficient of error terms for constraint regime and labor exchange use	0.517 (0.326)	0.578* (0.312)	-0.754* (0.445)	-0.694*** (0.247)
Log partial-likelihood	-1789.58	-1748.63		
Observations	2009	2009		
Selected Parameters from Other Specifications				
Land area owned	0.161*** (0.054)	0.130** (0.052)	0.002 (0.050)	0.027 (0.056)

Starting values were taken from estimates of a two-stage probit model of the decision to use labor exchange with a correction for sample selection into working capital constrained or unconstrained regimes. The standard errors in parentheses are based on the Huber/White/sandwich robust estimator of variance, adjusted for clustering in sample design. South Sulawesi is the omitted province. The omitted season indicator in the working capital constraint equation is for annual crops.
* Significant at 10%; ** Significant at 5%; *** Significant at 1%.

4.6 Estimating Participation in Labor Exchange Under Working Capital Constraints Using the EM Algorithm

As shown in the previous section, using informed but arbitrary assignment rules to classify households as working capital constrained improves the ability of the empirical model to explain many of the determinants of the decision to use labor exchange under imperfect factor markets, with some limitations. The Expectation-Maximization (EM) algorithm provides an attractive alternative to arbitrary classification for the type of model estimated here. The algorithm treats the unobserved working capital constraint as an incomplete data problem and uses the properties of the data to select the parameters of the model and the assignment of observations to regimes that maximize the value of the likelihood function.

The primary shortcoming of the EM algorithm in this setting is that the likelihood function for this switching regression with a discrete dependent variable is not well behaved. The presence of local maxima and minima makes models of this type notoriously difficult to estimate. Because the EM algorithm relies on iterative estimation of the likelihood function for different separations of the data, it runs the risk of encountering peaks or valleys as it moves along the likelihood function, which would make it impossible to identify the global maximum. In applying the EM algorithm to the labor exchange model, I was unable to achieve convergence of the algorithm at commonly accepted convergence criteria. However, if more liberal convergence criteria are applied the parameter estimates from late iterations suggest a substantial reassignment of observations to regimes and a new set of estimates of the labor exchange model.

These estimates provide interesting evidence on the determinants of participation in labor exchange.

4.6.1 An EM Algorithm for the Discrete Choice Endogenous Switching Regression

Although early versions of the EM algorithm appeared elsewhere, the seminal paper by Dempster, Laird and Rubin (1977) provides the first general version of the algorithm and its properties and gives the algorithm its name.[73] The algorithm provides an approach to maximum likelihood estimation for incomplete data. In the empirical model of labor exchange with imperfect capital markets, the data are incomplete in the sense that the indicator k_i from (4.5) that identifies households that are working capital constrained in each season is not observed. This data omission leads to the incomplete data form of the likelihood function L^I in (4.4). The complete data form of the likelihood function that could be estimated if k_i were observed for each observation is L^C in equation (4.6). The EM algorithm estimates the parameters of the incomplete data likelihood function by taking advantage of its relationship to the complete data form of the likelihood function, as described below.

The approach of the EM algorithm for this model is to start with an estimate of parameters from the complete data form of the likelihood function, $\hat{\beta}_1^0$, $\hat{\beta}_2^0$, $\hat{\gamma}^0$, $\hat{\sigma}_{1u}^0$, and $\hat{\sigma}_{2u}^0$, for some separation of the data, $k = (k_1,...,k_n)$, where the superscript indexes iterations of the algorithm and a zero superscript refers to starting values of the parameter

[73] For an expanded treatment on the EM algorithm, see McLachlan and Krishnan (1997).

estimates. These estimates are used to construct a new indicator, $\hat{\pi}_i^1$, equal to the expected value of the working capital constraint indicator

$$\begin{aligned} \hat{\pi}_i^1 &= E\left(k_i \mid y_i, X, W, \hat{\beta}_1^0, \hat{\beta}_2^0, \hat{\gamma}^0, \hat{\sigma}_{1u}^0, \hat{\sigma}_{2u}^0\right) \\ &= \Pr\left(k_i = 1 \mid y_i, X, W, \hat{\beta}_1^0, \hat{\beta}_2^0, \hat{\gamma}^0, \hat{\sigma}_{1u}^0, \hat{\sigma}_{2u}^0\right) \\ &= \Phi\left(W_i \hat{\gamma}^0\right). \end{aligned} \tag{4.10}$$

The computation of this predicted marginal probability of household *i* being working capital constrained is the E-step of the algorithm. The vector $\hat{\pi}^1 = \left(\hat{\pi}_1^1, ..., \hat{\pi}_n^1\right)$ provides the sufficient statistics of the complete data given the incomplete data. In the M-step, the parameters of the likelihood function are estimated again with $\hat{\pi}_i^1$ replacing k_i in the likelihood function in (4.6), which in log form becomes (with iteration superscripts removed)

$$\begin{aligned} LLF_i^C &= L^C\left(\beta, \gamma, \sigma_{1u}, \sigma_{2u} \mid y, \pi, X, W\right) \\ &= \sum_i \Big\{ y_i \pi_i \ln \Phi_2\left(X_{1i}\beta_1, W_i\gamma, \rho_{1u}\right) + y_i\left(1-\pi_i\right) \ln \Phi_2\left(X_{2i}\beta_2, -W_i\gamma, -\rho_{2u}\right) \\ &+ \left(1-y_i\right)\pi_i \ln \Phi_2\left(-X_{1i}\beta_1, W_i\gamma, -\rho_{1u}\right) + \left(1-y_i\right)\left(1-\pi_i\right) \ln \Phi_2\left(-X_{2i}\beta_2, -W_i\gamma, \rho_{2u}\right) \Big\}. \end{aligned} \tag{4.11}$$

The expectation $\hat{\pi}_i^1$ is not binary like k_i, but takes on values in the [0,1] interval because each observation could belong to either regime with some positive probability. In the next iteration of the algorithm, the E-step creates a new vector $\hat{\pi}^2$ of predicted probabilities that households are working capital constrained and the M-step obtains new estimates of the parameters $\hat{\beta}_1^2$, $\hat{\beta}_2^2$, $\hat{\gamma}^2$, $\hat{\sigma}_{1u}^2$, and $\hat{\sigma}_{2u}^2$. This procedure is repeated until successive iterations of the algorithm do not change the estimated coefficients more than some small convergence criterion. Approximate asymptotic standard errors for the coefficients are obtained numerically from the inverse of the second derivative matrix of the log likelihood function, taking into account the clustered sample design.

According to Dempster, Laird and Rubin (1977), the EM algorithm provides consistent estimates of the parameters from the incomplete data form of the likelihood function and will converge to a maximum (subject to limitations of the data) provided that the likelihood function satisfies two criteria. First, the incomplete data form of the likelihood function must equal the sum of the complete data form of the likelihood function over all possible realizations of the missing data

(4.12) $$L^I(\beta,\gamma,\sigma_{1u},\sigma_{2u} \mid y,X,W) = \sum_{\in K} L^C(\beta,\gamma,\sigma_{1u},\sigma_{2u} \mid y,k,X,W),$$

where the set *K* of all possible realizations of the *k* vector has 2^n elements. Second, successive iterations of the algorithm must increase the value of the likelihood function in order to guarantee that the procedure will move toward a maximum. I will not prove that these two criteria are met for likelihood functions L^I in (4.4) and L^C in (4.6). However, a simple exercise, not repeated here, verifies that the first criterion is met in the simple case where n=3. I also do not establish the second criterion here, but successive iterations of the EM algorithm implemented for this model met that criterion as well.

It is important to keep in mind that the EM algorithm cannot claim to identify the true realization of the working capital constraint classification vector, *k*. Such as task would require identification of *k*'s 2^n arguments, which is not feasible. Rather, the EM algorithm provides estimates of the parameters of the incomplete data form of the likelihood function, which in cases like this one cannot be estimated through a standard Newton-Raphson algorithm. The EM algorithm does not solve the incomplete data problem. It provides a tractable approach to working around it in order to estimate the parameters of the incomplete data model.

In estimating the model for the decision to participate in labor exchange via the EM algorithm, I used parameter estimates from Model 5 in Table 4.4 as starting values to compute $\hat{\pi}^1$ in the E-step of the first iteration. To my knowledge, this study is the first application of the EM algorithm for a discrete choice endogenous switching regression model.[74]

4.6.2 Estimates of the Model of Labor Exchange Participation from the EM Algorithm

In estimation via the EM algorithm, the routine to maximize the log likelihood function in (4.11) converged for the first fourteen iterations and then failed. At each iteration, the value of the log likelihood function was higher than in the previous one. In addition, the maximum difference between the parameter estimates in the current iteration ($\alpha_j^t = \left(\beta_j^t, \gamma_j^t, \sigma_{j1u}^t, \sigma_{j2u}^t\right)$ for j=1,…,p, where p is the total number of parameters) and those from the last iteration fell monotonically from one iteration to the next. A summary of the value of the log likelihood function and the maximum difference in matched parameter estimates between iterations is provided in Table 4.5. These results suggest that the algorithm itself was well behaved.

Table 4.5: Summary of Results of the EM Algorithm by Iteration

Iteration	lnL	$\max\left(\alpha_j^t - \alpha_j^{t-1}\right)$
0	-1789.58	0.0000
1	-1811.60	2.3823
2	-1808.70	0.3228
3	-1804.92	0.3278
4	-1799.59	0.2793
5	-1793.01	0.2231
6	-1785.71	0.1746
7	-1778.11	0.1359
8	-1770.46	0.1058
9	-1762.87	0.0826
10	-1755.38	0.0647
11	-1747.98	0.0507
12	-1740.67	0.0409
13	-1733.44	0.0387
14	-1726.28	0.0367

The failure of convergence at the fifteenth iteration probably indicates a discontinuity in the likelihood function in the neighborhood of the parameter values for that iteration. This is a common outcome in models with multiple discrete endogenous variables. Unfortunately, the failure to converge implies that I cannot conclude that the resulting parameter estimates are the ones that maximize the likelihood function. Because the algorithm achieved successively higher values of the log likelihood function and the parameter estimates were converging, the estimates from the fourteenth iteration may still

[74] I would like to thank Marc Nerlove for suggesting the EM algorithm for this problem.

be informative. In addition, these parameters achieved a higher value of the log likelihood function than those in Models 5 and 6 from the discrete choice endogenous switching regressions in Table 4.4 for their respective separations of the data, *k*. The values of the log likelihood in Models 5 and 6 were –1789.58 and –1748.63, respectively. In the fourteenth iteration of the EM algorithm, the value of the log likelihood function was –1726.28. A likelihood ratio test of these models could be performed if they were hierarchically nested, which is not the case here.

Results of the fourteenth iteration of the EM algorithm are presented as Model 7 in Table 4.6. The standard errors presented in parentheses are based on a quadratic approximation to the log likelihood function centered on the estimated parameter values. If the log likelihood is not quadratic, then this approximation of the variance is poor. This probably explains the low standard errors in the working capital constraint equation in the first panel in Table 4.6. Standard errors for the labor exchange participation equations for the two regimes are more reasonable, but the results for the working capital constraint equation suggest that results of the hypothesis tests indicated by the asterisks in Table 4.6 should be treated with caution.

The parameter estimates of the determinants of working capital constraints differ considerably from those in Models 5 and 6, which is not surprising given that these estimates reflect a different implied separation of the observations into constrained and unconstrained regimes. In Model 5, 39.7 percent of the observations were classified as working capital constrained. In the results from the fourteenth iteration of the EM algorithm, 44.4 percent of the observations were more likely to lie in the constrained regime in the sense that $\hat{\pi}_i^{14} > .5$. However, a substantial number of observations were reclassified by the EM algorithm, with only 55.7 percent of those identified as working capital constrained in Model 5 being more likely to fall into this regime based on the results of the EM algorithm. Despite the differences in parameter estimates for the working capital constraint equation between Models 5 and 6 and Model 7, only one variable changed sign.

For the labor exchange participation equations, the parameter estimates from Model 7 are much closer in magnitude to those in Models 5 and 6. Only two coefficients in these equations changed sign in Model 7, but neither was significant in any of the models. Although I view these results with some caution, the estimates of the probability of participating in labor exchange in each regime in Model 7 lead to some intriguing alternative results that suggest that these parameter estimates may be a better fit of the model. Most notably, the estimated effect of working capital on labor exchange use for unconstrained households is smaller in Model 7 and is insignificant. This satisfies the prediction from the model in Chapter 2 that working capital holdings have no effect on the labor exchange participation decision for unconstrained households. It suggests that households in the unconstrained regime in the new division of the sample have a higher probability of being unconstrained in Model 7 than in Models 5 and 6, where this parameter was significant.

Plot size has a positive effect on the probability of using labor exchange for both constrained and unconstrained households in Model 7 as in Models 5 and 6, but Wald tests indicate that this effect is significantly larger for the constrained group only in Model 7. Plot size affects the probability of using labor exchange by changing the size of returns to teamwork and by increasing liquidity in this specification. This result for Model 7 is consistent with a larger positive liquidity effect for working capital constrained households, as predicted by the model for households in the lower half of the working capital endowment distribution. Also, the area of other plots planted this season has a significant (insignificant) negative effect on labor exchange use for constrained (unconstrained) households in Model 7. These significance outcomes are opposite to those in Models 5 and 6. This result could arise if liquidity constrained households are less able than unconstrained households to meet their labor needs on other plots through the labor market. Many of the other estimates of the labor exchange participation determinants are consistent with those in Models 5 and 6. Although the results for the estimates from the EM algorithm are qualified by the failure of the algorithm to converge by accepted convergence criteria, they suggest a meaningful reclassification of the data that provide a somewhat better fit to the model of labor exchange developed here.

Table 4.6: Estimates of Probability of Participating in Labor Exchange with Unobserved Working Capital Constraints Using the EM Algorithm

Estimates of γ : **Determinants of the Probability of Being Working Capital Constrained**	Model (7)
Value of land owned net of outstanding land debt, 1998, Rp. mn	-0.010*** (0.001)
Value of non-farm business, household assets net of outstanding related debt, 1998, Rp. mn	-0.016*** (0.002)
Value of livestock and farm equipment net of outstanding farm debt, 1998, Rp. mn	-0.009* (0.005)
Share of village households using credit	0.331*** (0.112)
Village average interest rate	0.030*** (0.002)
Village average interest rate squared	-0.000*** (0.000)
Indicator for use of HYV seeds	-0.794*** (0.036)
Ln of number of household members	0.028* (0.016)
Household head age (years)	-0.001* (0.000)
Household head education (years)	-0.013*** (0.004)
Indicator for white collar household head occupation	-0.071 (0.107)
Lampung province indicator	0.214*** (0.035)
Central Java province indicator	-0.586*** (0.026)
East Java province indicator	-0.623*** (0.022)
West Nusa Tenggara province indicator	-0.552*** (0.017)
North Sulawesi province indicator	-0.301*** (0.022)
Rainy season indicator	1.130*** (0.035)
Dry season indicator for both dry seasons	0.898*** (0.028)
Constant	-0.527*** (0.088)

Table 4.6: (continued)

Estimates of β_1, β_2**:** **Determinants of the Probability of Using Labor Exchange on this Plot**	Working Capital Constrained	Working Capital Unconstrained
	Model	
	(7)	(7)
Working capital: credit taken or outstanding plus savings by season, Rp. mn.		-0.008 (0.005)
Value of non-land business, household, farm assets net of credit financing, 1998, Rp. mn	-0.003 (0.005)	0.002 (0.004)
Number of household members	-0.042** (0.020)	-0.042* (0.023)
Indicator for simple irrigation	0.348* (0.197)	0.476*** (0.163)
Indicator for plot being owned, not leased	-0.213* (0.111)	-0.186* (0.096)
Indicator that corn is at least half of the value of production on this plot	-0.029 (0.217)	0.270** (0.135)
Indictor for HYV seeds used in corn production	1.077*** (0.353)	0.849*** (0.158)
Ln of plot area	0.193*** (0.072)	0.114** (0.052)
Area of other plots planted this season by this household	-0.183** (0.087)	-0.107 (0.066)
Share of village sample plots within 10% of this plot's area, by season	1.113*** (0.348)	0.934*** (0.344)
Average village hourly wage for time rate contracts, by season (Rp. '000)	-0.524* (0.303)	-0.687** (0.320)
Average village hourly wage × Indicator for net seller of labor	0.760*** (0.267)	0.954*** (0.312)
Average village hourly wage × Indicator for net buyer of labor	1.050*** (0.282)	1.273*** (0.324)
Household head age (years)	-0.009*** (0.003)	-0.003 (0.003)
Household head education level (years)	-0.008 (0.014)	-0.016 (0.014)
Lampung province indicator	-1.480*** (0.188)	-1.229*** (0.138)
Central Java province indicator	-0.310** (0.139)	-0.431*** (0.127)
East Java province indicator	-1.775*** (0.307)	-1.721*** (0.306)
West Nusa Tenggara province indicator	-0.780*** (0.216)	-0.910*** (0.212)
North Sulawesi province indicator	-0.976*** (0.379)	-1.171*** (0.282)
Constant	0.946*** (0.288)	-0.832*** (0.312)

Correlation coefficient of error terms for constraint regime and labor exchange use	-0.729*** (0.076)	-0.893*** (0.052)
Log partial-likelihood	-1726.28	
Observations	2009	2009

The standard errors in parentheses are based on the Huber/White/sandwich robust estimator of variance, adjusted for clustering in sample design. South Sulawesi is the omitted province. The omitted season indicator in the working capital constraint equation is for annual crops. * Significant at 10%; ** Significant at 5%; *** Significant at 1%.

4.7 Conclusion

This empirical investigation of the determinants of agricultural labor exchange explains many of the characteristics of the farming technology, asset endowment distribution, and labor and credit markets that condition labor exchange use for this sample of Indonesian farmers. The results also provide considerable support for the model of labor exchange use across various modes of production presented in Chapter 2.

I find strong evidence for returns to teamwork in rice and corn production, the crops for which labor exchange is most commonly used. Until now, there has been little rigorous evidence of returns to teamwork in agriculture. This establishes a necessary condition for labor exchange. It also refutes claims made elsewhere that returns to teamwork are likely to be small in agriculture. Indeed, because the model demonstrates that returns to teamwork are a necessary condition for labor exchange, the considerable presence of labor exchange in developing countries across the globe provides additional empirical evidence for returns to teamwork in agriculture.

The estimates of determinants of participation in labor exchange teams in which all households are assumed to be working capital constrained validate the pattern of effects of liquidity on labor exchange use for constrained households predicted in the model from Chapter 2. At low levels of working capital endowments, liquidity has a positive effect on participation in labor exchange, but this effect reverses direction in the upper half of the distribution of working capital endowments. The negative relationship between working capital and labor exchange use is the one most commonly cited in the literature on labor exchange. However, the confirmation of a positive relationship for households with low holdings of working capital explains the counterexamples in the literature. Chibnik and de Jong (1989) and Worby (1995) show that use of labor exchange increased along with liquidity from new commercial farming opportunities in Peru and Zimbabwe. Farmers in these settings were relatively poor, and probably had low holdings of working capital before the introduction of new commercial crops. These empirical results show that the institution of labor exchange can be an engine of growth in farm incomes at low levels of development. Labor exchange provides a source of team labor for poor farmers when credit and labor markets are imperfect. Aside from landless laborers, these farmers are at the greatest disadvantage in the development process.

The results from the models in which all households are assumed to be working capital constrained also show that the size of the local paid labor market reduces demand for labor exchange even after controlling for wage levels. I argue that this is evidence of transactions costs in the paid labor market. The responsiveness of participation in labor exchange teams to wages in the paid labor market shows that labor exchange coexists with paid labor markets in the Indonesian sample. Labor exchange raises welfare and further contributes to development by providing a substitute source of team labor.

When the sample is separated into cohorts based on whether the working capital constraint is binding, estimates from discrete choice endogenous switching regressions in Models 5 and 6 verify a number of other predictions of the model. The distribution of land and other assets, imperfections in the credit market, crops grown, and wage rates are all shown to affect the use of labor exchange in a manner consistent with the theory. One important inconsistency with the theory from Models 5 and 6—that working capital holdings significantly affect the decision to participate in labor exchange for households that are not liquidity constrained—is overturned when the model is estimated using the EM algorithm.

5 Conclusion

This dissertation investigates the economics of agricultural labor exchange in rural areas of developing countries. In labor exchange, farmers form a work team that supplies labor on each team member's farm in succession. The central features of these arrangements include joint agricultural production by team members, the reciprocal exchange of labor time (possibly delayed) between each pair of team members, no monetary payments, and the rotating accrual of private benefits to the host farmer on each farm. Although labor exchange teams have existed for centuries and remain common in much of Southeast Asia, Africa, and parts of Latin America, they have received almost no attention from development economists. I investigate the motivation for the formation of labor exchange teams by considering the individual farmer's decision to participate in labor exchange. The analysis focuses on the role of the two most prominent motivations for labor exchange raised in the sociological literature: credit and labor market imperfections and the technological benefits of teamwork. These motivations are heavily influenced by the farmer's endowments of working capital, land (or rights to its use), and labor (via household size). I also investigate how participation in labor exchange is constrained by the characteristics of the exchange arrangement in the context of agricultural production. The reciprocal exchange of labor time and the team production setting suggest that the local distribution of land and the degree of heterogeneity in crop choice, plot size, irrigation technology and human capital may all condition labor exchange use.

I develop a theoretical model of labor exchange in which an agricultural household chooses land area and allocates labor supply and demand across activities and labor arrangements given a production technology with positive returns to teamwork, possible quantity constraints in the credit market, and transaction costs for labor transactions. In addition, non-household labor exhibits moral hazard and so must be supervised. This model expands the set of possible modes of production defined by net position in the labor market as described by Eswaran and Kotwal (1986). The model explains demand for labor exchange as a function of a farmer's endowments of land, capital assets, and household size, working capital constraints and search costs for finding labor or off-farm employment. In the empirical section of the research, I test some assumptions and implications of the model for the decision to participate in labor exchange for a sample of Indonesian farmers from the PATANAS data set, which I helped to collect in 1999. The analytical and empirical models substantially expand current knowledge about how factor market imperfections, returns to teamwork and other technological considerations contribute to the adoption and persistence of this non-market institution. The results have important implications for our understanding of factor transactions in rural areas of developing countries, for the role of non-market institutions in the process of development, and for how contractual forms in labor transactions are conditioned by technology.

By allowing for possible returns to teamwork and the availability of labor exchange, the theoretical model in Chapter 2 generalizes existing models of the organization of agricultural production. The models by Feder (1985), Eswaran and Kotwal (1986), and

Carter and Zimmerman (2000), rule out the simultaneous purchase and sale of labor by working capital constrained households. Supervision costs associated with employing non-household labor make it unprofitable to finance labor expenditures on farm by supplying labor off-farm. The model developed here shows that this common phenomenon can be explained by positive returns to teamwork. Lemma 2.1 shows that when external (paid or exchange) labor exhibits moral hazard, returns to teamwork are a necessary condition for simultaneously employing labor on farm and supplying labor off farm. A corollary is that returns to teamwork are a necessary condition for labor exchange. There are other explanations for simultaneously hiring and supplying labor in the market, including contractual indivisibilities, specialization, land fragmentation (Bardhan, 1982), and skill heterogeneity within the household (Sadoulet, de Janvry and Benjamin, 1998). However, of these returns to teamwork is the only relevant explanation for the decision to use labor exchange.

Results from Chapter 2 also show that because each hour of labor employed under labor exchange must be reciprocated with labor time off farm, labor exchange can only substitute for team labor demand from the market. I rule out a mode of production in which farmers simultaneously sell labor in the market, hire market labor and participate in labor exchange as empirically improbable. Therefore, for agricultural activities that exhibit returns to teamwork, labor exchange offers an alternative to simultaneously buying and selling labor in the market. Which mode of production obtains depends on relative search costs for each type of labor transaction.

In the model by Eswaran and Kotwal (1986), four modes of production arise along an activity continuum along a scale of access to working capital. A farmer's holdings of working capital completely determine the optimal choice of mode of production, from *laborer-cultivators*, to *self-cultivators*, to *small capitalists*, to *large capitalists* as working capital increases. With possible returns to teamwork and the availability of labor exchange, I show that 12 distinct modes of production arise as a function of the four market labor regimes identified by Eswaran and Kotwal, as well as the degree of returns to teamwork and the relative size of search costs for each type of labor transaction. The new typology indicates that, with returns to teamwork and depending on relative search costs, labor exchange may be optimal for farmers with working capital holdings consistent with any of the first three market labor regimes. Only those with the largest farms, who are in the upper tail of the working capital distribution, would never find it profitable to choose labor exchange. They devote all of their time to supervision of hired labor and can obtain labor teams from the market.

The final results from the theoretical model concern the effects of household working capital, land, and labor endowments on demand for labor exchange. For households that are not working capital constrained, demand for labor exchange is independent of holdings of working capital and land endowments. However, if the working capital constraint is binding, the effects of working capital or land endowments (which differ only by a scalar in this model) on demand for labor exchange differ by mode of production. With returns to teamwork, farmers at the bottom of the working capital distribution will operate as laborer-cultivators using labor exchange. For these farmers, an increase in working capital endowment has a positive effect on demand for labor exchange as more land is brought in, raising demand for team labor. For self-cultivators using labor exchange, whether greater access to working capital increases or decreases demand for labor exchange depends on the production and supervision technologies, on preferences, and on the relative substitutability of team size or labor time for land. For small capitalists using labor exchange, an increase in working capital has a positive endowment effect on demand for labor exchange and a negative substitution effect through improved access to paid labor. In summary, the model from Chapter 2 shows that the effect of working capital holdings on demand for labor exchange is positive at low levels of working capital and may be positive or negative as working capital endowments increase. Observers have claimed a negative overall effect of working capital holdings on labor exchange. If true, then the relationship does turn negative near the top of the working capital distribution, leading to an inverted U shape.

The main empirical results are presented in Chapter 4. The model in Chapter 2 identifies returns to teamwork as a necessary condition for the use of labor exchange, so I first test for the presence of returns to teamwork in the Indonesian data in order to validate this result. For this test, I restrict the sample to rice and corn farmers because farmers growing these crops are the most likely to use labor exchange. The test, based on estimation of a plot-level Cobb-Douglas agricultural production function, involves comparing estimates of the productivity of piece-rate labor to piece-rate team labor. By restricting the comparison to piece-rate labor contracts, I remove the incentive effect of these high-powered contracts, which are more common in team production, from the pure team effect. Estimates across several specifications, including pooled OLS, pooled IV, household random effects IV, and village fixed effects, all support higher productivity of labor performed in teams. This establishes the necessary condition for use of labor exchange for this sample. In addition, these results provide rare evidence of returns to teamwork in agriculture and they contribute to limited empirical evidence of a productivity advantage of team production in general. This finding suggests that the model of the organization of agricultural production with returns to teamwork and labor exchange developed here is more appropriate for this sample than the reduced model of Eswaran and Kotwal (1986). Moreover, this evidence contradicts the claim by Eswaran and Kotwal (1986) that returns to teamwork are not a valid motivation for the hierarchical employer-employee relationship in agriculture. Because returns to teamwork are a necessary condition for labor exchange, labor exchange teams everywhere serve as counterexamples to their claim. Where labor exchange teams are found or where farmers simultaneously hire and supply labor to the market, the model developed here may be a more appropriate representation of the organization of production.

In Chapter 4, I develop an empirical model of participation in labor exchange subject to working capital constraints based on the analytical model of labor exchange demand in Chapter 2. The effects of endowments, transaction costs and prices on the labor exchange participation decision should be comparable to their effects on labor exchange demand since these effects should be robust at the corner solution to the demand problem. I take several approaches to estimating the participation decision because the effects of many of these determinants of labor exchange depend on whether the farmer is working capital constrained, and this constraint is unobserved. I begin by assuming that all households are working capital constrained and estimate the plot-level decision to use labor exchange in a pooled probit model and a probit model with household random effects. The estimates provide broad support for the model of labor exchange in Chapter 2. The most striking result is that the effect of working capital endowments on the decision to use labor exchange displays the inverted U shape hypothesized. Using quintiles of season-specific working capital holdings as explanatory variables, I show that moving from quintiles one or two to the third quintile of working capital holdings increases the probability of participating in labor exchange, but that subsequent increases in working capital quintiles, starting with the third or the fourth, reduce the probability of using labor exchange. If the characterization of all households as working capital constrained is correct, this suggests that access to capital reduces reliance on non-market labor exchanges only for farmers in the upper half of the working capital distribution. On average, farmers with working capital endowments below the median use labor exchange to enhance the productivity of additional capital.

Also in this model, an increase in the wage rate for paid labor increases the probability of participating in labor exchange for net buyers of labor, which suggests active substitution between paid labor and exchange labor. It must be that both market and non-market labor sources are available to many of these Indonesian farmers. Also, in the random effects specification, an increase in the size of the local agricultural labor force reduces the probability of using labor exchange, even controlling for the wage rate. A larger supply of workers in the paid labor market reduces reliance on non-market exchange, independent of the price, suggesting that there are transaction costs to hiring paid labor in these villages. In other results from this model, plots using simple irrigation are significantly more likely to be included in labor exchange, which indicates that labor exchange use is consistent with at least this low level output-enhancing investment. Household size reduces the probability of using labor exchange in the pooled probit models, as expected.

In order to test whether these results are robust to the assumption that all households are working capital constrained, I develop two assignment rules to divide the sample by season into working capital constrained and unconstrained regimes based on observed holdings of working capital. Under the first rule, all households with no savings, borrowing or lending are classified as constrained. Most of the households classified as constrained under this rule fell in the first two quintiles of working capital holdings. Under the second rule, households in the third working capital quintile were added to the constrained cohort from the first rule. Separately for each assignment rule, I estimated a three-equation model explaining the probability of being working capital constrained as well as the decision to participate in labor exchange as a function of being constrained or unconstrained under the assignment rule. The resulting model leads to a discrete endogenous switching regression, which I estimated by maximum likelihood.

The first equation in this model explains the determinants of the probability of being working capital constrained. Estimates for this equation were similar under either assignment rule. Results show that the value of land owned and the value of livestock and farm equipment were negatively associated with the probability of being working capital constrained. Also, households in villages with larger credit markets are significantly less likely to be constrained. Under the second assignment rule, the village interest rate has a negative effect on the probability of being constrained. This indicates that the role of the interest rate operates more through savings than borrowing. The probability of being working capital constrained also declines with household head education and if the household head has a white-collar occupation.

Estimates of the discrete endogenous switching regression provide mixed support for the method of sample separation based on the two assignment rules. Both assignment rules appear to classify too many households as unconstrained. As a result, most estimated effects of the decision to participate in labor exchange do not differ significantly between households in the two regimes. However, the estimated correlation coefficients between the working capital constraint equation and the corresponding labor exchange participation equation were significant, although weakly in all but one case.

Estimates of the decision to participate in labor exchange from the switching regressions provided substantial support for the model in Chapter 2, but again provide mixed evidence on the appropriateness of the method of sample separation used here. Because constrained households have little or no working capital holdings under the two assignment rules, it is not possible to test for the inverted U shape in the relationship between working capital holdings and participation in labor exchange for constrained households. For households classified as unconstrained under both assignment rules, working capital holdings had a significant negative effect on the probability of participating in labor exchange. This contradicts the predictions of the theoretical model in Chapter 2 for unconstrained households. When considered along with the previous results, this provides evidence that neither assignment rule properly classifies households as unconstrained in access to capital.

In the model specification including land endowments (area owned) rather than plot size constraints (operated plot area and area of other plots), the value of non-land assets has a negative effect on the probability of using labor exchange for working capital constrained households and no significant effect for unconstrained households. This supports the regime assignment rules used here and suggests that these assets provide some liquidity, probably as collateral, for constrained households. The estimated effects of land endowments and household size provide further support for the regime switching model, which treats households with relatively large working capital endowments as unconstrained. Under either assignment rule, land area owned has no effect on the probability of using labor exchange for unconstrained households, as predicted by the theory. Land endowments have a significant positive effect on labor exchange use for constrained households, which is consistent with many of these households being in the *laborer-cultivator* market labor regime. Also, an increase in household size significantly reduces the probability of using labor exchange for working capital constrained households, but not for unconstrained households. This is consistent with the theoretical model. Demand for labor exchange is independent of household size in unconstrained households operating in modes of production that include labor market participation due to separability of production and consumption decisions. In working capital constrained households, larger households are less likely to use labor exchange if the substitution effect of household labor for market labor dominates the time endowment effect. The estimated effects of simple irrigation technology, high-yielding variety seeds, and the wage rate from the regime switching models are generally consistent with results from the model in which all households are treated as constrained. Also, in the preferred estimates from both specifications, the share of village plots within ten percent of the area of the observed plot increases the probability of using labor exchange. The estimated coefficients for this variable, which measures the size of the pool of potential labor exchange teammates, indicate that homogeneity of plot size is an important constraint on the operation of labor exchange teams.

Based on these results, it appears that applying the additional structure provided by the switching regression model provided additional insights into the likely determinants of labor exchange participation, but it is not possible to draw a definitive conclusion about the most appropriate division of the sample into working capital constrained and unconstrained regimes.

In a final attempt to overcome the unobserved working capital constraint classification, I estimated the switching regression model for labor exchange participation using the EM algorithm. This algorithm treats the unobserved constraint as a missing data problem and uses the properties of the data to assign observations to regimes and solve for the maximum likelihood estimates of the parameters. Although the algorithm failed to converge according to accepted convergence criteria, a more relaxed convergence criterion permits examination of the final iteration before failure. Estimates of the model from this iteration provide further insights into the determinants of labor exchange. For example, working capital holdings have no significant effect on the probability of using labor exchange for unconstrained households for this model. However, there is no significant effect for constrained households either. The latter result could arise from a linear specification for the working capital variable if the true relationship is nonlinear, or inverted-U shaped. Also, plot size has a positive effect on the probability of using labor exchange for both constrained and unconstrained households, as in the earlier results from the regimes switching models based on arbitrary regime assignment. However, the size of this effect is significantly larger for constrained households only in the results using the EM algorithm. This suggests a larger positive liquidity effect of land area for constrained households and is consistent with the theory.

These results demonstrate the dependence of this type of labor arrangement on production technology. Labor exchange arises only in the presence of returns to teamwork and is constrained by the plot sizes of team members. The latter result suggests that labor exchange is better suited to villages with a relatively homogenous distribution of land and where land fragmentation is limited.

These results also have important implications for our understanding of the role of labor exchange in the process of development. Labor exchange does not exist only in very remote villages with thin labor markets and limited commercial development, as a symptom of “backward agriculture”. Rather, these results show that the labor exchange institution operates in many areas simultaneously with active labor markets, substituting for the market when paid labor transaction costs are high. Farmers show surprising flexibility in their use of labor exchange across seasons and activities for the same plot. Their participation in these teams responds to local wage rates and to the size of the agricultural labor force. Although the availability of labor exchange appears to reduce reliance on the labor market, thereby slowing the market’s development, labor exchange provides an important source of team labor when labor markets fail.

If the process of economic development is characterized by a reduction in the agricultural labor force as workers migrate to other sectors, labor exchange may be an important source of team labor during the development transition. The finding of an inverted U shape in the relationship of working capital holdings to labor exchange participation suggests that labor exchange can provide a vehicle for poor farmers achieve efficiency gains in the presence of returns to teamwork in production. As access to capital improves, farmers with limited capital holdings can use labor exchange as a means to expand their operations when labor markets are thin. In this way, labor exchange complements the process of development at its early stages. Sociologists have debated whether labor exchange will continue to operate as rural areas of developing countries become more developed. These results suggest that the agricultural labor exchange institution is likely to persist much longer than many have suspected, and may only be eliminated in the final stages of development, when farms become more agglomerated and mechanization is widespread.

Appendix A: Details of First-Order Conditions and Comparative Statics for the Labor Exchange Model

(A1) The Model of Labor Exchange

The Lagrangean for the problem in equation (2.6) is

$$G = f\left(A, T\bar{n}_H - R - F + n_M - s(L) - c_F F/T - c_M n_M - c_E n_E, n_M + n_E + \bar{n}_H\right) + w(F - n_M) - v(A - \bar{A}) + u(R)$$
$$+ \mu\left[T\bar{n}_H - R - F - n_E - s(L) - c_F F/T - c_M n_M - c_E n_E\right]$$
$$+ \lambda\left[\bar{B} + w(F - n_M) - v(A - \bar{A})\right]$$

The corresponding Kuhn-Tucker first-order necessary conditions for maximization are

(A1.a) $\phi_A \equiv f_1 - (1+\lambda)v = 0, \quad A > 0,$

(A1.b) $\phi_R \equiv -f_2 + u' - \mu = 0, \quad R > 0,$

(A1.c) $\phi_F \equiv -f_2(1 + c_F/T) + (1+\lambda)w - \mu(1 + c_F/T) \leq 0, \quad F \geq 0,$

(A1.d) $\phi_M \equiv f_2(1 - s' - c_M) + f_3 - (1+\lambda)w - \mu(s' + c_M) \leq 0, \quad n_M \geq 0,$

(A1.e) $\phi_E \equiv -f_2(s' + c_E) + f_3 - \mu(1 + s' + c_E) \leq 0, \quad n_E \geq 0,$

(A1.f) $\phi_\mu \equiv T\bar{n}_H - R - F - n_E - s(L) - c_F F/T - c_M n_M - c_E n_E \geq 0, \quad \mu \geq 0,$

(A1.g) $\phi_\lambda \equiv \overline{B} + w(F - n_M) - v(A - \overline{A}) \geq 0$, $\lambda \geq 0$,

where, $\phi_i = \partial G / \partial i$ for i=A, R, F, μ, and λ, and $\phi_j = \partial G / \partial n_j$ for j=M,N. Also, f_i, i=1,2,3, denotes the first partial derivative of the production function with respect to its *i*th argument. In condition (A1.a), A>0 by the assumption that these households are cultivators and that A is essential. In condition (A1.b), R>0 by the assumption that the marginal utility of leisure is infinite when R=0. Each other coupling of inequalities in conditions (A1.c)-(A1.g) are subject to a third condition for complementary slackness that requires the product of the left-hand-sides of the two inequalities to equal zero.

The concavity of $U(\cdot,\cdot)$, the strict quasiconcavity of $f(\cdot,\cdot,\cdot)$ and the convexity of $s(\cdot)$ guarantee that there is a unique solution to the problem in (6), and that the first-order conditions are sufficient for a maximum.

(A2) Comparative statics for $\frac{dn_E^*}{d\overline{B}}$ for self-cultivating farmers using labor exchange

Here, I determine the effect of an increase in access to working capital on demand for labor exchange for self-cultivating farmers using labor exchange. The relevant choice variables are A, R, and n_E. Hours worked on farm, *H*, are determined as a residual category in the time constraint, which has already been substituted into the production function in the Lagrangean in (A1) in this Appendix. Also, $H > 0$ implies $\mu = 0$. To simplify the analysis, I substitute the working capital constraint for *A* in the Lagrangean. The resulting first order conditions are:

(A2.1.a) $\quad -f_2 + u' = 0$, and

(A2.1.b) $\quad -\left(s' + c_E\right) f_2 + f_3 = 0$,

where arguments of the production and utility functions have been omitted for simplicity, and subscripts denote first partial derivatives with respect to the numbered argument.

Totally differentiating with respect to $\overline{B}$ yields the following system of equations

$$\begin{bmatrix} f_{22}+u'' & (s'+c_E)\, f_{22}-f_{23} \\ (s'+c_E)\, f_{22}-f_{23} & (s'+c_E)^2\, f_{22}-2(s'+c_E)\, f_{23}-f_2 s''+f_{33} \end{bmatrix} \begin{bmatrix} \dfrac{dR^*}{d\bar{B}} \\ \dfrac{dn_E^*}{d\bar{B}} \end{bmatrix} = \begin{bmatrix} \dfrac{f_{12}}{v} \\ \dfrac{(s'+c_E)\, f_{12}-f_{13}}{v} \end{bmatrix} \tag{A2.2}$$

Let Δ denote the 2-by-2 matrix in (A2.2). By the strict quasiconcavity of $f(\cdot,\cdot,\cdot)$ and the strict concavity of $u(\cdot)$, it must be true that $|\Delta|>0$. Applying Cramer's Rule, the effect of an increase in the working capital endowment on demand for labor exchange is given by

$$\frac{dn_E^*}{d\bar{B}} = \frac{1}{|\Delta| v}\left[f_{12}\, f_{23} - f_{13}\, f_{22} - u''\left(f_{13} - (s'+c_E) f_{12}\right)\right]. \tag{A2.3}$$

By strict quasiconcavity of the production function and substitutability of factors in production $(f_{ii}>0 \text{ and } f_{ij}>0, i\neq j)$, and by concavity of the utility of leisure $(u''<0)$, a sufficient condition for $\frac{dn_E^*}{d\bar{B}}>0$ is $f_{13}-(s'+c_E)f_{12}\geq 0$, or , after substituting from (A2.1.b),

$$f_2\, f_{13} - f_3\, f_{12} \geq 0\,.$$

Similarly, a sufficient condition for $\frac{dn_E^*}{d\bar{B}} < 0$ is

$$f_2 f_{13} - f_3 f_{12} < \frac{f_{12} f_{23} - f_{13} f_{22}}{u''}.$$

(A3) Comparative statics for $\frac{dn_E^*}{d\bar{B}}$ for small-capitalist-cultivators using labor exchange

For farmers operating as small capitalists with labor exchange, the choice variables are *A*, *R*, *H*, n_M, and n_E. After substituting the time and working capital constraints for *H* and *A*, respectively, the relevant first order conditions are

(A3.1.a) $$-f_2 + u' = 0,$$

(A3.1.b) $$-\frac{w}{v} f_1 + (1 - s' - c_M) f_2 + f_3 = 0,$$ and

(A3.1.c) $$-(s' + c_E) f_2 + f_3 = 0.$$

Evaluating the comparative statics for this system of equations is substantially more complicated than for the case of self-cultivators using labor exchange presented in (A2). The added complexity arises because of the higher order of the problem and because n_M enters all three arguments of the production function following the substitution of the two constraints. Using Cramer's Rule, the effect of an increase in working capital on demand for labor exchange is given by

(A3.2)

$$\frac{dn_E^*}{d\bar{B}} = \frac{1}{|\Delta|}\begin{vmatrix} f_{22}+u'' & -f_{2M} & \dfrac{f_{12}}{v} \\ -f_{2M} & -\dfrac{w}{v}f_{1M} - s''f_2 + (1-s'-c)\,f_{2M} + f_{3M} & -\dfrac{f_{1M}}{v} \\ (s'+c)\,f_{22} - f_{23} & -s''f_2 - (s'+c)\,f_{2M} + f_{3M} & \dfrac{(s'+c)\,f_{12} - f_{13}}{v} \end{vmatrix},$$

where Δ is the Hessian matrix for the Langrangean for this problem, search costs for paid labor and exchange labor are assumed to be identical $(c_M = c_E = c)$, and

$$f_{im} = -\frac{w}{v}f_{i1} + (1-s'-c)f_{i2} + f_{i3}, \text{ for } i = 1, 2, \text{or } 3.$$

A second order sufficiency condition for the solution to equations (A3.1) to be a maximum is that the determinant of Δ be negative. Therefore, the sign of $\frac{dn_E^*}{d\bar{B}}$ is the opposite of the sign of the 3-by-3 determinant in (A3.2). In general, the sign of this expression is indeterminate.

If leisure is fixed, the sign of the effect of additional working capital on demand for labor exchange is given by the sign of the determinant of the second trailing principal minor of the detailed matrix in (A3.2):

(A3.3)
$$sign\left\{\frac{dn_E^*}{d\bar{B}}\right\} = sign\left\{\frac{w}{v}\Big((s'+c)-(s'+c)^2\Big)C_{33} \;\; +\frac{w}{v}\big(1-2(s'+c)\big)C_{32} + \;\big(1-(s'+c)\big)C_{13} \;\; -\frac{w}{v}C_{22}-C_{12}+\left(\frac{w}{v}f_{11}-f_{12}\right)f_2 s''\right\},$$

where C_{ij} is the (signed) cofactor for the *i*th row and *j*th column of the Hessian matrix of second derivatives of the production function. Although the expression on the left-hand-side of (A3.3) cannot be signed in general, if $s'+c>1$, then $\frac{dn_E^*}{d\bar{B}}<0$. To see this, note that under constant returns to scale in the production function there are decreasing returns in any two of the arguments: $C_{33} = f_{11}f_{22} - f_{12}^2 > 0$ and $C_{22} = f_{11}f_{33} - f_{13}^2 > 0$. By strict quasiconcavity of the production function and substitutability of all factor pairs, $f_{ii}<0$, and $f_{ij}>0, i \neq j$. This implies the last four terms in (A3.3) are all negative. The second term is negative as long as $s'+c>.5$. A sufficient condition for negativity of the first and third terms is $s'+c>1$.

(A4) Comparative statics for $\frac{dn_E^*}{d\bar{B}}$ for laborer-cultivators using labor exchange

Farmers operating in this mode of production have *A*, *R*, *H*, *F*, and n_E as choice variables. After substituting the time and working capital constraints for *H* and *A*, respectively, the relevant first order conditions are

(A4.1.a) $$-f_2 + u' = 0,$$

(A4.1.b) $$\frac{w}{v} f_1 - \left(1 + \frac{c_F}{T}\right) f_2 = 0, \text{ and}$$

(A4.1.c) $$-\left(s' + c_E\right) f_2 + f_3 = 0.$$

For simplicity, assume equal search costs per worker in labor exchange and off-farm work, $c_E = c_F / T = c$. Using Cramer's Rule, the effect of an increase in working capital on demand for labor exchange in this mode of production is given by

(A4.2) $$\frac{dn_E^*}{d\bar{B}} =$$

$$\frac{1}{|\Delta|}\begin{vmatrix} f_{22}+u'' & -\frac{w}{v}f_{12}+(1+c)f_{22} & \frac{f_{12}}{v} \\ -\frac{w}{v}f_{12}+(1+c)f_{22} & \frac{w^2}{v^2}f_{11}-2\frac{w}{v}(1+c)f_{12}+(1+c)^2 f_{22} & -\frac{w}{v^2}f_{11}+\frac{(1+c)}{v}f_{12} \\ (s'+c)f_{22}-f_{23} & \frac{w}{v}(s'+c)f_{12}+(1+c)(s'+c)f_{22}+\frac{w}{v}f_{13}-(1+c)f_{23} & \frac{(s'+c)f_{12}-f_{13}}{v} \end{vmatrix}$$

where Δ is the Hessian matrix for the Langrangean for this problem. Equation (A4.2) can be simplified considerably into

(A4.3) $$\frac{dn_E^*}{d\bar{B}} = \frac{1}{|\Delta|}\frac{u''}{v}\left(\frac{w}{v}(1+c)(s'+c)C_{33} + \frac{w}{v}(1+c)C_{32} + (1+c)^2 C_{31}\right),$$

where C_{ij} is the (signed) cofactor for the *i*th row and *j*th column of the Hessian matrix of second derivatives of the production function. The expression in (A4.3) is positive. A second order sufficiency condition for the solution to equations (A4.1) to be a maximum is that the determinant of Δ be negative. The strict quasiconcavity of $f(\cdot,\cdot,\cdot)$ and the strict concavity of $u(\cdot)$ ensure that this is satisfied, and also implies that $u'' < 0$. The cofactor $C_{33} = f_{11}f_{22} - f_{12}^2$ is positive by constant returns to scale of the production function. The other two cofactors are positive by the quasiconcavity of $f(\cdot,\cdot,\cdot)$ and the assumption of substitutability of all pairs of its arguments.

(A5) Comparative statics for $\frac{dn_E^*}{d\bar{n}_H}$ for self-cultivators using labor exchange

After substituting the time and working capital constraints, the Lagrangean for this problem is

(A5.1) $$G = f\left(\frac{\bar{B}}{v} + \bar{A}, T\bar{n}_H - R - s(n_E) - c_E n_E, n_E + \bar{n}_H\right) - \bar{B} + u(R)$$

and the relevant first order conditions are:

(A5.2.a) $- f_2 + u' = 0$, and

(A5.2.b) $-(s' + c_E)f_2 + f_3 = 0$.

Totally differentiating with respect to $\bar{B}$ and applying Cramer's Rule leads to the expression

(A5.3) $$\frac{dn_E^*}{d\bar{n}_H} = \frac{1}{|\Delta|}\left\{u''\left(T(s' + c_E)f_{22} - Tf_{23} + (s' + c_E)f_{23} - f_{33}\right) - \left(f_{22}f_{33} - f_{23}^2\right)\right\},$$

where Δ is the Hessian matrix for the Langrangean for this problem. By strict quasiconcavity of the production function, substitutability of factors in production, and strict concavity of $u(\cdot)$, $|\Delta| > 0$, $u'' < 0$, $f_{ii} < 0$, and $f_{ij} > 0, i \neq j$. Therefore, the term

$u''\left(T\left(s' + c_E\right)f_{22} - Tf_{23}\right)$ is positive. By these properties and constant returns to scale in the production function, the remaining terms are negative.

Appendix B: The 1998-99 PATANAS Survey Sample Villages

Table B.1: Village Roster, 1998-99 PATANAS survey*

Province	**Village** **District** **Main crops**						
Village ID:	1	2	3	4	5	6	7
Lampung	**Gunung Rejo** L. Selatan banana	**Air Naningan** Tangganus coffee	**Sumber Rejo** L. Tengah rice	**Komering Putih** L. Tengah cassava	**Beringin** L. Utara pepper	**Kota Napal** L. Utara sugarcane	
Central Java	**Cepogo** Boyolali milk	**Karangwungu** Klaten rice	**Kwadungan Gun.** Temanggung tobacco	**Karang Tengah** Banjarnegara vegetables	Larangan Brebes red onion	Karangmoncol Pemalang rice	**Mojoagung** Pati sugarcane
East Java	**Gerih** Ngawi rice	**Selosari** Kediri rice	Terung Kulon Sidoarjo rice	Sungun Legowo Gresik shrimp	Brondong Lamongan fish	**Wiyurejo** Malang vegetables	
West Nusa Tenggara	Gonjar Lombok Teng. rice, tobacco	**Sengkol** Lombok Teng. rice	**Karang Baru** Lombok Timur garlic, onion	**Plampang** Sumbawa cattle	**Sukadamai** Dompu cashew		
North Sulawesi	Rumoong Atas Minahasa clove	**Pakuweru** Minahasa coconut	Wailan Minahasa horticulture	Karegesan Minahasa nutmeg	**Mogoyunggung** Bolaang M. rice		
South Sulawesi	Margolembo Luwu rice	**Baroko** Enrekang vegetables		**Selli** Bone rice, soybean	Polo Padang Tator coffee	**Rumbia** Jeneponto corn, mango	Batupanga Polmas chocolate

* Villages in bold type had agricultural labor exchange in 1998-99.

Table B.2: Number of Household Observations by Village, 1998-99 PATANAS survey

Province	Village, by ID Number 1	2	3	4	5	6	7	Subtotal
Lampung	42	43	43	49	44	45		266
Central Java	49	45	45	41	39	35	47	301
East Java	49	48	48	26	27	45		243
West Nusa Tenggara	44	47	28	47	47			213
North Sulawesi	43	44	45	38	43			213
South Sulawesi	43	46		44	41	43	41	258
TOTAL								1,494

Appendix C: First stage Estimates of Factor Demands for Production Function Estimation

Table C.1.1: First stage Estimates of Piece Rate Labor Hours for Production Function Estimation by Instrumental Variables

Dependent Variable: Piece rate labor hours	**Coef.**	**Std. Err.**	**t**	**P>t**
Area planted	0.303	0.057	5.300	0.000
Technical irrigation dummy	1.248	0.158	7.910	0.000
Simple irrigation dummy	-0.495	0.151	-3.280	0.001
Value of farm equipment	0.013	0.018	0.750	0.453
Dryland dummy	-0.732	0.188	-3.890	0.000
Household head age	0.048	0.254	0.190	0.851
Household head education	0.016	0.085	0.190	0.847
Rainy season 1998-99 dummy	-0.656	0.922	-0.710	0.477
Dry season 1998 dummy	-0.572	0.925	-0.620	0.536
Province dummy for Lampung	0.415	0.198	2.100	0.036
Province dummy for Central Java	-0.086	0.225	-0.380	0.703
Province dummy for East Java	0.327	0.211	1.550	0.122
Province dummy for West Nusa Tenggara	-0.197	0.212	-0.930	0.352
Province dummy for North Sulawesi	0.082	0.241	0.340	0.734
Share of agric. laborers in village adults, '98 census	-2.603	0.612	-4.260	0.000
Village average interest rate	0.002	0.001	2.890	0.004
Share of total village area planted in rice	1.668	0.295	5.660	0.000
Village median distance to market for crops	0.093	0.021	4.360	0.000
Number of children age 0-5 years	0.109	0.142	0.770	0.441
Number of children age 6-11 years	-0.227	0.118	-1.930	0.054
Number of male children age 12-15 years	0.057	0.168	0.340	0.733
Number of female children age 12-15 years	-0.190	0.166	-1.140	0.253
Number of male children age 16-19 years	0.092	0.166	0.560	0.578
Number of female children age 12-15 years	0.134	0.172	0.780	0.437
Number of males age 20 years and older	0.258	0.181	1.430	0.154
Number of females age 20 years and older	0.225	0.220	1.020	0.306
Village average rice price by season	0.908	0.351	2.590	0.010
Village average male wage by season	0.236	0.404	0.580	0.560
Plot inheritance dummy	-0.276	0.107	-2.560	0.010
Constant	-0.659	1.484	-0.440	0.657
N	1031			
Adjusted R^2	0.281			
p-value: F(29,1001)	0.000			

Partial R-squared of excluded instruments: 0.0886
Test of excluded instruments:
F(15, 1001) = 6.48
Prob > F = 0.0000

Table C.1.2: First stage Estimates of Piece Rate Team Labor Hours for Production Function Estimation by Instrumental Variables

Dependent Variable: Piece rate team labor hours	**Coef.**	**Std. Err.**	**t**	**P>t**
Area planted	0.025	0.035	0.710	0.477
Technical irrigation dummy	0.242	0.097	2.490	0.013
Simple irrigation dummy	0.200	0.093	2.150	0.031
Value of farm equipment	0.020	0.011	1.830	0.068
Dryland dummy	-0.195	0.116	-1.680	0.093
Household head age	0.158	0.156	1.010	0.313
Household head education	0.092	0.053	1.760	0.079
Rainy season 1998-99 dummy	-2.924	0.568	-5.150	0.000
Dry season 1998 dummy	-2.940	0.569	-5.160	0.000
Province dummy for Lampung	0.587	0.122	4.820	0.000
Province dummy for Central Java	1.917	0.139	13.840	0.000
Province dummy for East Java	0.305	0.130	2.350	0.019
Province dummy for West Nusa Tenggara	0.458	0.130	3.520	0.000
Province dummy for North Sulawesi	1.085	0.148	7.310	0.000
Share of agric. laborers in village adults, ‘98 census	-1.480	0.377	-3.930	0.000
Village average interest rate	0.000	0.001	-0.170	0.866
Share of total village area planted in rice	1.503	0.182	8.280	0.000
Village median distance to market for crops	0.054	0.013	4.140	0.000
Number of children age 0-5 years	-0.163	0.087	-1.870	0.062
Number of children age 6-11 years	-0.008	0.073	-0.120	0.907
Number of male children age 12-15 years	-0.108	0.103	-1.040	0.299
Number of female children age 12-15 years	-0.214	0.102	-2.100	0.036
Number of male children age 16-19 years	0.112	0.102	1.100	0.271
Number of female children age 12-15 years	-0.143	0.106	-1.350	0.177
Number of males age 20 years and older	-0.014	0.111	-0.120	0.903
Number of females age 20 years and older	0.050	0.135	0.370	0.710
Village average rice price by season	0.375	0.216	1.740	0.083
Village average male wage by season	-2.150	0.249	-8.630	0.000
Plot inheritance dummy	0.176	0.066	2.660	0.008
Constant	2.736	0.914	2.990	0.003
N	1031			
Adjusted R^2	0.309			
p-value: F(29,1001)	0.000			

Partial R-squared of excluded instruments: 0.1292
Test of excluded instruments:
F(15, 1001) = 9.90
Prob > F = 0.0000

Table C.1.3: First stage Estimates of Other Hired Labor Hours for Production Function Estimation by Instrumental Variables

Dependent Variable: Other hired labor hours	Coef.	Std. Err.	t	P>t
Area planted	0.148	0.046	3.250	0.001
Technical irrigation dummy	-0.572	0.126	-4.550	0.000
Simple irrigation dummy	-0.339	0.120	-2.830	0.005
Value of farm equipment	0.108	0.014	7.600	0.000
Dryland dummy	-0.266	0.150	-1.770	0.077
Household head age	0.116	0.202	0.570	0.568
Household head education	0.122	0.068	1.790	0.074
Rainy season 1998-99 dummy	-0.009	0.734	-0.010	0.990
Dry season 1998 dummy	-0.086	0.736	-0.120	0.907
Province dummy for Lampung	-0.234	0.158	-1.490	0.138
Province dummy for Central Java	-0.772	0.179	-4.310	0.000
Province dummy for East Java	-0.537	0.168	-3.200	0.001
Province dummy for West Nusa Tenggara	0.126	0.169	0.750	0.456
Province dummy for North Sulawesi	0.326	0.192	1.700	0.090
Share of agric. laborers in village adults, '98 census	1.738	0.487	3.570	0.000
Village average interest rate	0.000	0.001	-0.500	0.614
Share of total village area planted in rice	-0.669	0.235	-2.850	0.004
Village median distance to market for crops	-0.066	0.017	-3.870	0.000
Number of children age 0-5 years	0.291	0.113	2.570	0.010
Number of children age 6-11 years	0.082	0.094	0.880	0.380
Number of male children age 12-15 years	0.343	0.134	2.560	0.011
Number of female children age 12-15 years	-0.181	0.132	-1.370	0.170
Number of male children age 16-19 years	-0.141	0.132	-1.070	0.286
Number of female children age 12-15 years	-0.300	0.137	-2.180	0.029
Number of males age 20 years and older	-0.069	0.144	-0.480	0.634
Number of females age 20 years and older	-0.060	0.175	-0.350	0.730
Village average rice price by season	-0.802	0.280	-2.870	0.004
Village average male wage by season	0.071	0.322	0.220	0.825
Plot inheritance dummy	0.005	0.086	0.060	0.950
Constant	5.294	1.182	4.480	0.000
N	1031			
Adjusted R^2	0.208			
p-value: F(29,1001)	0.000			

Partial R-squared of excluded instruments: 0.0541

Test of excluded instruments:

F(15, 1001) = 3.81

Prob > F = 0.0000

Table C.1.4: First stage Estimates of Household Labor Hours for Production Function Estimation by Instrumental Variables

Dependent Variable: Household labor hours	Coef.	Std. Err.	t	P>t
Area planted	0.231	0.055	4.180	0.000
Technical irrigation dummy	0.187	0.152	1.230	0.220
Simple irrigation dummy	-0.295	0.146	-2.030	0.043
Value of farm equipment	-0.001	0.017	-0.050	0.957
Dryland dummy	-0.071	0.182	-0.390	0.697
Household head age	-0.100	0.245	-0.410	0.683
Household head education	-0.386	0.082	-4.680	0.000
Rainy season 1998-99 dummy	-0.869	0.891	-0.980	0.330
Dry season 1998 dummy	-0.840	0.893	-0.940	0.347
Province dummy for Lampung	-0.557	0.191	-2.920	0.004
Province dummy for Central Java	-0.668	0.217	-3.070	0.002
Province dummy for East Java	-1.519	0.204	-7.460	0.000
Province dummy for West Nusa Tenggara	-0.430	0.204	-2.100	0.036
Province dummy for North Sulawesi	-1.537	0.233	-6.600	0.000
Share of agric. laborers in village adults, ‘98 census	-0.908	0.591	-1.540	0.125
Village average interest rate	-0.003	0.001	-3.170	0.002
Share of total village area planted in rice	-0.522	0.285	-1.830	0.067
Village median distance to market for crops	0.025	0.021	1.230	0.221
Number of children age 0-5 years	0.088	0.137	0.650	0.519
Number of children age 6-11 years	-0.053	0.114	-0.470	0.640
Number of male children age 12-15 years	0.206	0.162	1.270	0.204
Number of female children age 12-15 years	0.147	0.160	0.920	0.358
Number of male children age 16-19 years	0.182	0.160	1.140	0.255
Number of female children age 12-15 years	0.358	0.167	2.150	0.032
Number of males age 20 years and older	0.327	0.175	1.870	0.062
Number of females age 20 years and older	0.391	0.213	1.840	0.066
Village average rice price by season	0.012	0.339	0.030	0.973
Village average male wage by season	0.326	0.391	0.830	0.404
Plot inheritance dummy	-0.036	0.104	-0.350	0.726
Constant	6.787	1.433	4.740	0.000
N	1031			
Adjusted R^2	0.171			
p-value: F(29,1001)	0.000			

Partial R-squared of excluded instruments: 0.0385
Test of excluded instruments:
F(15, 1001) = 2.67
Prob > F = 0.0005

Table C.1.5: First stage Estimates of Non-Labor Cost for Production Function Estimation by Instrumental Variables

Dependent Variable: Non-labor cost	Coef.	Std. Err.	t	P>t
Area planted	0.311	0.038	8.240	0.000
Technical irrigation dummy	0.191	0.104	1.830	0.067
Simple irrigation dummy	-0.440	0.099	-4.430	0.000
Value of farm equipment	0.083	0.012	7.020	0.000
Dryland dummy	-0.519	0.124	-4.180	0.000
Household head age	-0.133	0.168	-0.790	0.428
Household head education	0.076	0.056	1.350	0.177
Rainy season 1998-99 dummy	-0.214	0.608	-0.350	0.725
Dry season 1998 dummy	-0.451	0.610	-0.740	0.460
Province dummy for Lampung	0.214	0.130	1.640	0.101
Province dummy for Central Java	0.018	0.148	0.120	0.901
Province dummy for East Java	0.301	0.139	2.170	0.031
Province dummy for West Nusa Tenggara	0.017	0.140	0.120	0.903
Province dummy for North Sulawesi	1.388	0.159	8.730	0.000
Share of agric. laborers in village adults, ‘98 census	0.480	0.403	1.190	0.234
Village average interest rate	0.000	0.001	0.320	0.747
Share of total village area planted in rice	0.397	0.194	2.040	0.041
Village median distance to market for crops	0.052	0.014	3.720	0.000
Number of children age 0-5 years	-0.162	0.093	-1.740	0.083
Number of children age 6-11 years	-0.101	0.078	-1.300	0.195
Number of male children age 12-15 years	0.197	0.111	1.780	0.076
Number of female children age 12-15 years	0.089	0.109	0.820	0.414
Number of male children age 16-19 years	0.008	0.109	0.070	0.940
Number of female children age 12-15 years	0.089	0.114	0.780	0.435
Number of males age 20 years and older	0.493	0.119	4.130	0.000
Number of females age 20 years and older	0.218	0.145	1.500	0.133
Village average rice price by season	-0.348	0.232	-1.500	0.133
Village average male wage by season	-2.896	0.267	-10.860	0.000
Plot inheritance dummy	-0.069	0.071	-0.980	0.329
Constant	7.195	0.979	7.350	0.000
N	1031			
Adjusted R^2	0.307			
p-value: F(29,1001)	0.000			

Partial R-squared of excluded instruments: 0.1619
Test of excluded instruments:
F(15, 1001) = 12.90
Prob > F = 0.0000

Table C.2.1: First stage Estimates of Piece Rate Labor Hours for Production Function Estimation by Random Effects Instrumental Variables

Dependent Variable: Piece rate labor hours	Coef.	Std. Err.	t	P>t
Area planted	0.274	0.056	4.900	0.000
Technical irrigation dummy	1.123	0.158	7.100	0.000
Simple irrigation dummy	-0.405	0.150	-2.710	0.007
Value of farm equipment	0.011	0.019	0.580	0.563
Dryland dummy	-0.786	0.185	-4.250	0.000
Household head age	0.166	0.267	0.620	0.534
Household head education	0.044	0.089	0.500	0.618
Rainy season 1998-99 dummy	-0.708	0.869	-0.810	0.416
Dry season 1998 dummy	-0.641	0.871	-0.740	0.462
Province dummy for Lampung	0.297	0.210	1.420	0.156
Province dummy for Central Java	-0.069	0.239	-0.290	0.774
Province dummy for East Java	0.241	0.228	1.060	0.291
Province dummy for West Nusa Tenggara	-0.228	0.214	-1.070	0.287
Province dummy for North Sulawesi	0.057	0.256	0.220	0.822
Share of agric. laborers in village adults, ‘98 census	-2.550	0.629	-4.050	0.000
Village average interest rate	0.002	0.001	2.750	0.006
Share of total village area planted in rice	1.662	0.311	5.350	0.000
Village median distance to market for crops	0.095	0.021	4.420	0.000
Number of children age 0-5 years	0.101	0.148	0.680	0.495
Number of children age 6-11 years	-0.171	0.125	-1.370	0.172
Number of male children age 12-15 years	-0.011	0.180	-0.060	0.949
Number of female children age 12-15 years	-0.283	0.176	-1.610	0.107
Number of male children age 16-19 years	0.093	0.175	0.530	0.597
Number of female children age 12-15 years	0.122	0.182	0.670	0.503
Number of males age 20 years and older	0.146	0.196	0.750	0.456
Number of females age 20 years and older	0.183	0.229	0.800	0.423
Village average rice price by season	0.777	0.383	2.030	0.042
Village average male wage by season	0.124	0.428	0.290	0.772
Plot inheritance dummy	-0.238	0.107	-2.230	0.026
Constant	-0.648	1.497	-0.430	0.665
N	1031			
p-value: Wald chi(29)	0.000			

Table C.2.2: First stage Estimates of Piece Rate Team Labor Hours for Production Function Estimation by Random Effects Instrumental Variables

Dependent Variable: Piece rate team labor hours	Coef.	Std. Err.	t	P>t
Area planted	0.025	0.034	0.740	0.460
Technical irrigation dummy	0.177	0.097	1.810	0.070
Simple irrigation dummy	0.168	0.092	1.830	0.067
Value of farm equipment	0.018	0.012	1.490	0.137
Dryland dummy	-0.158	0.114	-1.390	0.163
Household head age	0.169	0.164	1.030	0.304
Household head education	0.091	0.055	1.670	0.095
Rainy season 1998-99 dummy	-2.894	0.535	-5.410	0.000
Dry season 1998 dummy	-2.941	0.537	-5.480	0.000
Province dummy for Lampung	0.567	0.129	4.390	0.000
Province dummy for Central Java	1.815	0.147	12.310	0.000
Province dummy for East Java	0.336	0.140	2.390	0.017
Province dummy for West Nusa Tenggara	0.437	0.132	3.320	0.001
Province dummy for North Sulawesi	1.019	0.158	6.460	0.000
Share of agric. laborers in village adults, ‘98 census	-1.453	0.387	-3.750	0.000
Village average interest rate	0.000	0.001	-0.080	0.936
Share of total village area planted in rice	1.534	0.191	8.020	0.000
Village median distance to market for crops	0.050	0.013	3.770	0.000
Number of children age 0-5 years	-0.155	0.091	-1.700	0.090
Number of children age 6-11 years	-0.020	0.077	-0.270	0.791
Number of male children age 12-15 years	-0.091	0.111	-0.820	0.412
Number of female children age 12-15 years	-0.247	0.108	-2.280	0.022
Number of male children age 16-19 years	0.112	0.108	1.040	0.299
Number of female children age 12-15 years	-0.119	0.112	-1.060	0.288
Number of males age 20 years and older	0.017	0.121	0.140	0.890
Number of females age 20 years and older	0.007	0.141	0.050	0.960
Village average rice price by season	0.385	0.236	1.630	0.102
Village average male wage by season	-1.984	0.263	-7.530	0.000
Plot inheritance dummy	0.145	0.066	2.210	0.027
Constant	0.025	0.034	0.740	0.460
N	1031			
p-value: Wald chi(29)	0.000			

Table C.2.3: First stage Estimates of Other Hired Labor Hours for Production Function Estimation by Random Effects Instrumental Variables

Dependent Variable: Other hired labor hours	Coef.	Std. Err.	t	P>t
Area planted	0.170	0.045	3.810	0.000
Technical irrigation dummy	-0.547	0.126	-4.340	0.000
Simple irrigation dummy	-0.315	0.119	-2.650	0.008
Value of farm equipment	0.110	0.015	7.190	0.000
Dryland dummy	-0.264	0.147	-1.790	0.073
Household head age	0.136	0.212	0.640	0.521
Household head education	0.124	0.070	1.760	0.079
Rainy season 1998-99 dummy	-0.051	0.692	-0.070	0.942
Dry season 1998 dummy	-0.083	0.694	-0.120	0.905
Province dummy for Lampung	-0.211	0.167	-1.270	0.206
Province dummy for Central Java	-0.700	0.191	-3.670	0.000
Province dummy for East Java	-0.626	0.182	-3.450	0.001
Province dummy for West Nusa Tenggara	0.105	0.170	0.610	0.539
Province dummy for North Sulawesi	0.356	0.204	1.750	0.080
Share of agric. laborers in village adults, ‘98 census	1.757	0.501	3.510	0.000
Village average interest rate	0.000	0.001	-0.300	0.765
Share of total village area planted in rice	-0.659	0.247	-2.660	0.008
Village median distance to market for crops	-0.066	0.017	-3.850	0.000
Number of children age 0-5 years	0.289	0.118	2.450	0.014
Number of children age 6-11 years	0.103	0.100	1.030	0.301
Number of male children age 12-15 years	0.340	0.143	2.380	0.017
Number of female children age 12-15 years	-0.195	0.140	-1.390	0.163
Number of male children age 16-19 years	-0.124	0.139	-0.890	0.372
Number of female children age 12-15 years	-0.289	0.145	-1.990	0.046
Number of males age 20 years and older	-0.119	0.156	-0.770	0.444
Number of females age 20 years and older	0.014	0.182	0.080	0.940
Village average rice price by season	-0.883	0.305	-2.900	0.004
Village average male wage by season	0.156	0.340	0.460	0.646
Plot inheritance dummy	0.048	0.085	0.560	0.573
Constant	5.174	1.191	4.340	0.000
N	1031			
p-value: Wald chi(29)	0.000			

Table C.2.4: First stage Estimates of Household Labor Hours for Production Function Estimation by Random Effects Instrumental Variables

Dependent Variable: Household labor hours	Coef.	Std. Err.	t	P>t
Area planted	0.226	0.054	4.180	0.000
Technical irrigation dummy	0.086	0.153	0.560	0.573
Simple irrigation dummy	-0.365	0.144	-2.530	0.011
Value of farm equipment	-0.001	0.018	-0.060	0.951
Dryland dummy	-0.048	0.178	-0.270	0.787
Household head age	-0.226	0.257	-0.880	0.380
Household head education	-0.383	0.085	-4.480	0.000
Rainy season 1998-99 dummy	-0.789	0.839	-0.940	0.347
Dry season 1998 dummy	-0.738	0.841	-0.880	0.380
Province dummy for Lampung	-0.493	0.202	-2.430	0.015
Province dummy for Central Java	-0.642	0.231	-2.780	0.006
Province dummy for East Java	-1.432	0.220	-6.510	0.000
Province dummy for West Nusa Tenggara	-0.355	0.206	-1.720	0.085
Province dummy for North Sulawesi	-1.489	0.247	-6.020	0.000
Share of agric. laborers in village adults, ‘98 census	-0.883	0.607	-1.450	0.146
Village average interest rate	-0.003	0.001	-3.220	0.001
Share of total village area planted in rice	-0.425	0.300	-1.420	0.157
Village median distance to market for crops	0.022	0.021	1.080	0.281
Number of children age 0-5 years	0.105	0.143	0.740	0.462
Number of children age 6-11 years	-0.050	0.121	-0.420	0.678
Number of male children age 12-15 years	0.197	0.173	1.130	0.257
Number of female children age 12-15 years	0.183	0.170	1.080	0.280
Number of male children age 16-19 years	0.203	0.169	1.200	0.230
Number of female children age 12-15 years	0.358	0.176	2.030	0.042
Number of males age 20 years and older	0.452	0.189	2.390	0.017
Number of females age 20 years and older	0.439	0.221	1.990	0.047
Village average rice price by season	0.091	0.370	0.250	0.806
Village average male wage by season	0.283	0.413	0.680	0.494
Plot inheritance dummy	-0.032	0.103	-0.310	0.756
Constant	6.940	1.445	4.800	0.000
N	1031			
p-value: Wald chi(29)	0.000			

Table C.2.5: First stage Estimates of Non-Labor Cost for Production Function Estimation by Random Effects Instrumental Variables

Dependent Variable: Non-labor cost	Coef.	Std. Err.	t	P>t
Area planted	0.307	0.038	8.140	0.000
Technical irrigation dummy	0.142	0.107	1.330	0.184
Simple irrigation dummy	-0.442	0.101	-4.390	0.000
Value of farm equipment	0.083	0.013	6.440	0.000
Dryland dummy	-0.509	0.124	-4.090	0.000
Household head age	-0.134	0.180	-0.750	0.455
Household head education	0.077	0.060	1.290	0.198
Rainy season 1998-99 dummy	-0.237	0.586	-0.400	0.686
Dry season 1998 dummy	-0.455	0.587	-0.770	0.439
Province dummy for Lampung	0.205	0.141	1.450	0.146
Province dummy for Central Java	0.033	0.161	0.210	0.836
Province dummy for East Java	0.289	0.154	1.880	0.060
Province dummy for West Nusa Tenggara	-0.002	0.144	-0.010	0.989
Province dummy for North Sulawesi	1.368	0.173	7.930	0.000
Share of agric. laborers in village adults, ‘98 census	0.479	0.424	1.130	0.259
Village average interest rate	0.000	0.001	0.560	0.574
Share of total village area planted in rice	0.417	0.210	1.990	0.046
Village median distance to market for crops	0.046	0.014	3.200	0.001
Number of children age 0-5 years	-0.169	0.100	-1.690	0.091
Number of children age 6-11 years	-0.092	0.084	-1.090	0.276
Number of male children age 12-15 years	0.160	0.121	1.320	0.187
Number of female children age 12-15 years	0.029	0.119	0.240	0.808
Number of male children age 16-19 years	0.026	0.118	0.220	0.826
Number of female children age 12-15 years	0.118	0.123	0.960	0.338
Number of males age 20 years and older	0.492	0.132	3.730	0.000
Number of females age 20 years and older	0.268	0.154	1.730	0.083
Village average rice price by season	-0.381	0.258	-1.470	0.140
Village average male wage by season	-2.758	0.288	-9.570	0.000
Plot inheritance dummy	-0.048	0.072	-0.670	0.502
Constant	7.105	1.009	7.040	0.000
N	1031			
p-value: Wald chi(29)	0.000			

Appendix D: The Definition of the Seasonal Measure of Working Capital

A number of practical issues had to be resolved in defining the measure of working capital from the 1998-99 PATANAS survey. As described in Chapter 3, I define working capital holdings as the sum of savings and new or outstanding credit. The most difficult issues in defining these variables concerned accounting for differences in savings and credit holdings across seasons and measuring the size of loans outstanding at any point in time. In order to obtain precise estimates of the determinants of the plot-specific labor exchange decision, it was necessary to estimate the probit model by season. This made it possible to take advantage of the very detailed plot-level data on labor demand by contract type and to capture the substantial variability in labor markets and growing conditions across seasons. However, savings were recorded only in March 1998 and March 1999. Profits from farming and other activities during the dry seasons in the first half of this year could have substantially changed the savings of households as they entered into the rainy season, when most production and the majority of labor exchanges occur. To account for this, I constructed a variable that measured savings in two seasons, the rainy season in 1998-99 and the combined dry seasons in 1998. Savings in the dry seasons equaled savings in March 1998. To construct savings in the rainy season, I added to March 1998 savings total income from all sources during the dry seasons (including income from farming, non-agricultural businesses, labor and asset sales) and subtracted estimates of food and non-food expenditures from March – October 1998. I also constructed a seasonal measure of credit outstanding.

In each season, I measured credit available for working capital as the sum of credit outstanding at the beginning of the season plus the value of loans taken during the season. For each loan outstanding between March 1998 and March 1999, the respondent was asked to provide the amount borrowed, the date of loan initiation, the interest rate or total amount due at termination, the value of payments made by March 1999, and the date when the final loan payment was due, if known.[75] For many loans, not all of this information was provided. In some cases, where interest rates were missing, I used median interest rates for other households in the village. Assuming uniform repayment rates, I constructed measures of credit outstanding in March 1998 and October 1998, the beginning of the dry seasons and rainy season, respectively. To these amounts, I added the value of loans taken during the season to construct the final seasonal credit variable. This approach to measuring seasonal credit use probably contributed some measurement error to the credit variable constructed. Nonetheless, I believe the approach provides the best possible measure of loans taken during the period.

[75] Other information was collected on each loan including the lending source and types and amounts of collateral used.

Appendix E: Marginal Effects and Elasticities of Probit Model Estimates

Table E.1: Marginal Effects and Elasticities of Probit Models from Table 4.3

Dependent Variable: Indicator for Labor Exchange Use by Plot, Season	Models							
	(1) Pooled Probit: Working capital in levels, land area owned		(2) Pooled Probit: Quintiles of working capital		(3) Pooled Probit: Plot size replaces land area owned		(4) Random Effects Probit	
	Marginal Effect	Elasticity	Marginal Effect	Elasticity	Marginal Effect	Elasticity	Marginal Effect	Elasticity
Working capital: credit taken or outstanding plus savings by season, Rp. mn.	-0.002	-0.065						
First quintile of working capital			0.033	0.143	0.032	0.142	0.021	0.106
Third quintile of working capital			0.088	0.110	0.089	0.113	0.072	0.104
Fourth quintile of working capital			0.067	0.143	0.069	0.149	0.046	0.115
Value of non-land business, household, and farm assets net of credit financing, 1998	-0.001	-0.055	0.000	-0.012	0.000	-0.022	-0.001	-0.085
Number of household members	-0.008	-0.491	-0.014	-0.696	-0.014	-0.692	-0.008	-0.435
Number of plantings on this plot, 1998-99	-0.038	-0.926	-0.046	-0.919	-0.043	-0.876	-0.019	-0.425
Indicator for simple irrigation	0.060	0.095	0.062	0.083	0.083	0.111	0.088	0.127
Indicator for plot being owned, not leased	-0.061	-0.539	-0.072	-0.529	-0.059	-0.454	-0.048	-0.417
Indictor for HYV seeds used in corn production	0.192	0.089	0.141	0.062	0.134	0.060	0.161	0.075
Land area owned	0.007	0.112	0.011	0.147				
Ln of plot area					0.031	-0.310	0.030	-0.341

(continued)…

	Models							
	(1)		(2)		(3)		(4)	
	Marginal Effect	Elasticity	Marginal Effect	Elasticity	Marginal Effect	Elasticity	Marginal Effect	Elasticity
Area of other plots planted this season by this household					-0.013	-0.043		
Share of village sample plots within 10% of this plot's area by season	0.166	0.245	0.129	0.157	0.127	0.159	0.120	0.170
Share of adults in village working as an agricultural laborer, 1998 census			-0.171	-0.298	-0.197	-0.351	-0.187	-0.375
Average village hourly wage for time rate contracts, by season	-0.069	--					-0.132	--
Average village hourly wage × Indicator for net seller of labor (*)	0.121	0.404					0.132	-0.002
Average village hourly wage × Indicator for net buyer of labor (*)	0.169	0.702					0.183	0.333
Household head age (years)	-0.001	-0.768	-0.002	-0.858	-0.002	-0.786	-0.001	-0.808
Household head education level (years)	-0.004	-0.232	-0.002	-0.097				
Lampung province indicator	-0.133	-0.625	-0.139	-0.514	-0.130	-0.484	-0.108	-0.445
Central Java province indicator	-0.059	-0.173	-0.058	-0.135	-0.041	-0.094	-0.022	-0.054
East Java province indicator	-0.125	-0.488	-0.139	-0.407	-0.130	-0.374	-0.120	-0.409
West Nusa Tenggara province indicator	-0.095	-0.313	-0.113	-0.302	-0.109	-0.292	-0.088	-0.255
North Sulawesi province indicator	-0.085	-0.162	-0.082	-0.103	-0.084	-0.114	-0.081	-0.132
Rainy season indicator	0.162	0.642	0.253	0.808	0.243	0.801	0.140	0.547
Dry season indicator for both dry seasons	0.168	0.492	0.258	0.604	0.248	0.598	0.148	0.425

The marginal effects of continuous variables are calculated as $\partial\Phi\left(X\hat{\beta}\right)/\partial X_i = \phi\left(\overline{X}\hat{\beta}\right)\hat{\beta}_i$, evaluated at the mean of the data. For binary variables, marginal effects are the difference in $\Phi\left(X\hat{\beta}\right)$ when the indicator changes from 0 to 1, with all other regressors evaluated at their means. Elasticities for all variables are calculated from the continuous variable form of the marginal effects. Elasticities of wages for net sellers and net buyers of labor (*) are the full elasticities.

Appendix F: Calculation of Marginal Effects for the Switching Regression in Equation (4.6)

I derive the analytical expression for the marginal effect of an explanatory variable, δ_j, on the marginal probability of being working capital constrained in the switching regression in equation (4.6),

$$\text{(F.1)} \qquad \frac{\partial \Pr(k_i = 1 \mid X, W)}{\partial \delta_j}.$$

I rely on the similarity of the likelihood function in (4.6) to the likelihood function for the bivariate probit model. The expression for the analogous marginal effect on marginal probabilities in the bivariate probit is provided in Christofides, Stengos, and Swidinsky (1997) and Christofides, Hardin, and Stengos, (2000). Assume that the explanatory variable, δ_j, appears in the X_1 matrix as β_{1j} and in the W matrix as γ_j. The marginal effect for the joint probability of using labor exchange and being working capital constrained is (ignoring observation subscripts)

$$\text{(F.2)} \qquad \frac{\partial \Pr(y = 1, k = 1 \mid X, W)}{\partial \delta_j} = \Phi_{LE1|WK1}\phi(W\gamma)\gamma_j + \Phi_{WK1|LE1}\phi(X_1\beta_1)\beta_{1j},$$

where

$$\Phi_{LE1|WK1} = \Phi\left(\frac{X_1\beta_1 - \rho_{1u}W\gamma}{\sqrt{1-\rho_{1u}^2}}\right) \text{ and } \Phi_{WK1|LE1} = \Phi\left(\frac{W\gamma - \rho_{1u}X_1\beta_1}{\sqrt{1-\rho_{1u}^2}}\right)$$

are the probability of participating in labor exchange conditional on being working capital constrained and the probability of being working capital constrained conditional on participating in labor exchange, respectively. Likewise, the marginal effect of a continuous explanatory variable on the joint probability of not using labor exchange and being working capital constrained is

(F.3) $$\frac{\partial \Pr(y = 0, k = 1 \mid X, W)}{\partial \delta_j} = \Phi_{LE0|WK1}\phi(W\gamma)\gamma_j - \Phi_{WK1|LE0}\phi(-X_1\beta_1)\beta_{1j},$$

where

$$\Phi_{LE0|WK1} = \Phi\left(\frac{-X_1\beta_1 + \rho_{1u}W\gamma}{\sqrt{1-\rho_{1u}^2}}\right) \text{ and } \Phi_{WK1|LE0} = \Phi\left(\frac{W\gamma - \rho_{1u}X_1\beta_1}{\sqrt{1-\rho_{1u}^2}}\right).$$

Because the marginal probability of being working capital constrained is the sum of the joint probabilities when working capital constrained,

(F.4) $$\Pr(k = 1 \mid X, W) = \Pr(y = 1, k = 1 \mid X, W) + \Pr(y = 0, k = 1 \mid X, W),$$

the expression for the marginal effect in (F.1) (and (4.8)) is the sum of (F.2) and (F.3), which simplifies to

$$\text{(F.5)} \quad \frac{\partial \Pr(k_i = 1 | X, W)}{\partial \delta_j} = \phi(W\gamma)\gamma_j + \Phi_{WK1|LE1}\phi(X_1\beta_1)\beta_{1j} - \Phi_{WK1|LE0}\phi(-X_1\beta_1)\beta_{1j}.$$

If the variable of interest does not appear in the labor exchange participation equation, then (F.5) simplifies to

$$\frac{\partial \Pr(k_i = 1 | X, W)}{\partial \delta_j} = \phi(W\gamma)\gamma_j,$$

which is the marginal effect in the univariate probit model.

Appendix G: Estimating the Switching Regression by Parts in Order to Satisfy Degrees of Freedom Restrictions: Estimates of (4.9.a) and (4.9.b) for Model 5

Table G.1: Estimates of the Probability of Participating in Labor Exchange Conditional on Working Capital Constraint Status

	Model 5	
	Equation (4.9.a)	Equation (4.9.b)
Estimates of γ . **Dependent Variable: Indicator for Being Working Capital Constrained**		
Value of land owned net of outstanding land debt, 1998, Rp. mn.	-0.003 (0.002)	-0.003 (0.002)
Value of livestock and farm equipment net of outstanding farm debt, 1998, Rp. mn.	-0.069*** (0.016)	-0.065*** (0.019)
Share of village households using credit	-1.213** (0.518)	-0.998* (0.546)
Ln of village average interest rate	-0.147* (0.079)	-0.123* (0.073)
Ln of number of household members	-0.190* (0.105)	-0.192* (0.112)
Indicator for white collar household head occupation	-1.019*** (0.342)	-0.949** (0.379)
Java regional indicator	-0.464** (0.213)	-0.419* (0.225)
Sulawesi regional indicator	-0.892*** (0.337)	-0.911*** (0.330)
Constant	1.268*** (0.482)	1.136** (0.482)
Estimates of β_1, β_2 . **Dependent Variable: Indicator for Labor Exchange Use**	**For Working Capital Constrained Households, β_1**	**For Working Capital Unconstrained Households, β_2**
Working capital: credit taken or outstanding plus savings by season, Rp. mn.		-0.012** (0.005)
Value of non-land business, household, farm assets net of credit financing, 1998, Rp. mn	-0.008 (0.008)	-0.004 (0.004)
Number of household members	-0.047 (0.036)	-0.041 (0.034)
Indicator for simple irrigation	0.162 (0.228)	0.282 (0.243)
Indictor for HYV seeds used in corn production	0.757* (0.423)	0.880*** (0.266)
Ln value of land area owned, 1998, Rp. mn.	-0.077 (0.061)	-0.270*** (0.046)
Share of village sample plots within 10% of this plot's area, by season	0.859 (0.633)	0.805** (0.386)

Average village hourly wage for time rate contracts, by season (Rp. '000)	-0.102 (0.311)	-0.624** (0.262)
Average village hourly wage × Indicator for net seller of labor	0.618** (0.253)	0.581*** (0.215)
Average village hourly wage × Indicator for net buyer of labor	0.877*** (0.268)	1.183*** (0.238)
Household head age (years)	-0.013* (0.007)	-0.005 (0.004)
Constant	-1.589*** (0.598)	0.343 (0.451)
Correlation coefficient	0.804*** (0.131)	0.634*** (0.234)
Log partial-likelihood	-1408.76	-1628.78
Observations	1930	1930
p-value: Wald chi2(10); Wald chi2(10)	0.0000	0.0000

Estimates are for the likelihood functions in (4.9.a) and (4.9.b). The assignment rule for working capital constraints is that a household is constrained in the given season if it has no borrowing, savings, or lending. Starting values were taken from estimates of a two-stage probit model of the decision to use labor exchange with a correction for sample selection into working capital constrained or unconstrained regimes. The standard errors in parentheses are based on the Huber/White/sandwich robust estimator of variance, adjusted for clustering in sample design. The p-values for Wald tests of joint significance of all regressors are presented. The Java regional indicator variable includes the provinces of Central Java and East Java. North Sulawesi or South Sulawesi provinces are indicated by the Sulawesi regional indicator. By this construction, the omitted provinces in the working capital constraint equation are Lampung and West Nusa Tenggara. All seasonal indicators are omitted in order to conserve degrees of freedom. * Significant at 10%; ** Significant at 5%; *** Significant at 1%.

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