Agricultural Innovation and Resource Management in Ghana

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I. Introduction: The Economic Issues

The goal of this research project is to understand the incentives faced by individuals with respect to land resource management and technological innovation in a rapidly changing rural economy. The study area is located in the forest-savanna transition zone of southern Ghana, where the farming system is undergoing a remarkable transition from an established system of maize and cassava intercropping for sale to urban consumers to intensive production of pineapple for export. In this paper, we focus on what factors could explain the adoption of pineapple. In particular we are concerned with two questions. First, why, despite its greater profitability, do almost no women farm pineapple? Second, not all men farm pineapple. What distinguishes those that do from those that don't? Instead of offering definitive answers, we provide an initial exploration of some of the potential explanations and the data that could be used to formulate more concrete answers. We intend for this paper not only to provide some insight into the economic process of innovation in southern Ghana, but also to make others aware of a rich new data source that is available for their use.

The paper is structured as follows. The remainder of section I provides an overview of the theoretical concerns that guided the project and closes with a discussion of the policy conclusions that this work will be able to provide. Section II provides a brief description of the survey instruments we used in data collection. Section III examines who farms which crops and what factors might potentially explain this. Section IV provides a brief conclusion.

We now turn to the four central economic issues which frame the work of this project.

A. Household Organization and Innovation

The decisions made by individuals are conditioned by the individual's interactions with other members of his or her household. Typically, empirical studies of farmer choice assume that individual choices are completely determined by the goals of the household as a whole. This assumption of a "unitary household" is convenient and innocuous in many contexts. However, economic theory is based on individual choice and there is theoretical justification for simple aggregation only under quite restrictive assumptions. A growing number of empirical studies within economics have found evidence against the unitary household hypothesis (Strauss and Thomas, 1994), and, of course, writers from outside of economics have long been skeptical of the economists' household model (Guyer 1981, Guyer and Peters 1987, Moock 1986). Recent work in economics has retreated from the unitary household model to the more general notion of efficient households - assuming only that households operate so that no reallocation could make everyone in the household better-off (Browning and Chiappori 1994). The minimal assumption of efficiency is sufficient to greatly simplify most analyses of production decisions - usually little change from the standard household approach is required.

There is evidence, however, that even the minimal assumption of intra-household efficiency is unwarranted in parts of west Africa (Dey, Von Braun and Webb, Udry 1996, Udry *et al* 1995). It becomes essential to recognize that the decisions made by one individual in a household are influenced not only by the economic environment which confronts the household as a whole, but also by the interactions between the members of the household. Moreover, in Ghana, gender is a fundamental determinant of an individual's opportunities and constraints in the realms of primary concern to this project. This is evident with respect to property rights: almost never could it be said that rights over a particular plot of land are vested in a conventionally-defined household. Moreover, the technological transformation at the heart of much of the work of the project is strongly correlated with gender: almost of all the farmers who have adopted pineapple are men, while women continue to specialize in producing maize and cassava. The conventional household model is simply impertinent: a reconceptualization of gender and household organization is necessary for an examination of this instance of technological innovation by farmers in Ghana.

Consider the example of financial markets. In the standard efficient household model, attention to individual choice should have no implications for the relationship between the use of fertility-enhancing techniques of production and the contractual environment within which the individual cultivator operates. All that would matter for production choices would be the access of the household as a whole to various markets (because efficiency would then require that resources obtained through these markets be redistributed within the household to achieve productive efficiency). However, given the evidence cited above that the efficient household model fails in at least one other west African setting, it is appropriate to explore the possibility that the choice of technique by an individual cultivator is affected by that individual's access to markets.

There is a large literature which suggests that the menu of available financial transactions depends upon the gender of the individual (AFP 1993). Preliminary analysis of the credit data provides evidence that men and women operate on very different scales in the financial markets. Women borrow and lend much, much less than their husbands. This may be of little consequence; a mere reflection of specialization within the household, with resources within the household being reallocated efficiently. If the efficient household model is not correct, however, this pattern may have important consequences for the farming practices of men and women.

B. Innovation and Learning

Second, the transformation of the region's farming system involves the adoption of a set of new technologies, including new planting materials, intensive use of agricultural chemicals, a transformation of the fallow system that had been used to maintain soil fertility, and the use of new output markets. How is knowledge about these new technologies generated and spread? There are formal mechanisms through which information is shared in the study area, including extension workers, farmer cooperatives, and crop exporters. Learning-by-doing by individual farmers as they experiment with the new technologies might play an important role in generating information. Finally, individuals might learn from each others' experiments. This process of *social learning* implies that early adopters of the new technology generate an externality for other cultivators.

There is a long tradition of empirical studies by economists of the adoption of new technologies in agriculture (Griliches 1957 is the seminal work. For reviews see Feder *et al*, 1985; Evenson and Westphal 1995). The paradigm through which agricultural innovation is understood by academics (and is implemented in practice by agricultural research and extension systems in Africa) is the diffusion of new technologies amongst farmers, initiated by agricultural extension officers and encouraged by the demonstration effect (e.g., Bindlish *et al*). There has been little formal work by economists which takes account of recent research in other disciplines (Richards 1985, 1990; Voss 1992; Opoku-Debrah 1994) which documents the important role of on-farm experimentation by farmers in developing new indigenous plant varieties, new agronomic techniques, and methods for integrating the modern varieties promoted by formal sector extension services into existing farming systems.

Amanor (1994), a geographer, provides an excellent account of on-farm experimentation by farmers in Ghana (also see Botchway). He documents intensive experimentation by farmers in southeast Ghana faced with severe environmental degradation. Farmers have introduced new crops, new systems of fallow management and new cultivation techniques as they struggle with the challenges of microclimate change, the spread of exotic new weeds, and dramatic changes in relative prices. The Learning and Farm Information II questionnaires (see appendix A) gathered data on experimentation with new cultivation practices during the current transition from maize and cassava cultivation to intensive export pineapple cropping in the study area.

It is well understood that there are potential inefficiencies in decentralized decision making if individual farmers do not take into account the external effects of experimentation on other farmers. An investment in experimentation by one farmer generates an externality because other farmers, through observation, benefit from the first farmer's experiments. The external effect is particularly important in the case of innovations (such as those which affect soil fertility) which require a minimum scale and which only gradually reveal their properties, because the scale of such experiments limits the number of replications any individual can execute. The externality is (largely) localized because the extreme variability of agro-climatic conditions within the region limits the geographic extent of the applicability of most new techniques of fertility maintenance. The question naturally arises: is there a mechanism through which the learning externality is internalized? Evidence from other countries is mixed. Two important recent papers which examine the empirical diffusion paths of (different) innovations in India reach different conclusions. Besley and Case (1994) conclude that the path is similar to that generated by individual agents who *do* take into account the external effects of their experimentation, while Foster and Rosenzweig (1995) find evidence of uninternalized externalities.[1]

Useful studies exist in the anthropological and historical literature of institutions which provide incentives for individuals to take account of learning externalities (e.g., Richards 1985, Dialla 1992, Chambers *et al*, 1989).[2] Our fieldwork, however, has revealed no social mechanism in the study area which could play this role. If such an institution exists, it is subtle.

The approach of this study is to use direct information on information flows to identify the importance of social learning. We have collected data on the extent and reliability of information flows between farmers (using the Farm Information I set of questionnaires, as well as the Farm Information II and Learning I and II questionnaires and the Individual Roster (the questionnaires are available at http://www.econ.yale.edu/~udry/ghanadata.html)). This can be used, together with information on farming outcomes in the first year and changing farming practices over the two years of the study to test the hypothesis that farmers learn from each other's experiences, and to measure the value (in terms of additional profits) that can be attributed

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[1]The innovative work of Besley and Case also highlights the limitations of working with data on the outcomes of the innovative process. They require a decade of panel data and some rather heroic assumptions to make progress. This is clearly an enormous step forward from the common cross-sectional regressions of adopters vs. non-adopters; however an examination of the local institutions which facilitate innovation may provide an alternative and perhaps more direct empirical approach to the forward-looking behavior they model.

[2]An example from Nigeria is the *Sarkin noma* ("chief farmer"). In some cases this honorary chieftaincy title is bestowed on the farmer who has developed exceptionally useful techniques. The *sarkin noma* title carries with it such economic benefits as claims on community labor, and priority access to external resources (see Smith 1955; Hill 1972).

to these information flows.

C. Institutions: Property Rights, Households and Innovation

Third, there is a close relationship between property rights over land and the incentives individuals face as they switch technologies. The different technologies available to cultivators in the study area have different implications for the dynamics of soil fertility. Therefore, the structure of the rights an individual has over a particular piece of land, and the obligations of that individual to others with complementary rights to that land will influence that person's choice of technology.

A good deal of work has been carried out by economists examining the relationship between fixed investment and land rights (Feder and Feeney; Migot-Adholla *et al*; Bassett and Crummey). Much land in the study area is cultivated under sharecropping arrangements, raising obvious issues of moral hazard in maintaining soil fertility. The study of property rights in land in Africa, however, is not simple: where assets have multiple purposes, rights over them are often multifaceted (see especially Berry 1993).[3] Moreover, there is evidence that the extent of one's rights over a particular plot is dependent on the investments one makes on that land (Besley) and in the community (Berry 1985). Studies based on the most detailed surveys of land rights in Africa (Migot-Adholla; Besley) provide only mixed evidence of any relationship between measures of the security of tenure and investment decisions.

This study focuses on tenure security at the individual level. Decisions regarding the application of fertility-enhancing techniques to particular plots are made by the individual

[3]Rights over trees on a particular piece of land, for example, might be held separately from rights over the land itself (Adegboye, 1969; Amanor).

cultivating that plot. If the efficient household model is not correct, then these individual decisions are conditioned by individual, as well as household, economic circumstances. Choices made by a woman with respect to the control of erosion on a plot she cultivates, for example, depend upon the security of her own control over that plot as well as on the rights over that plot which are vested in the household as a whole. It is essential, therefore, to investigate the tenurial relationship between *individuals* and the plots they cultivate. What determines the allocation of land to individuals within households? We examine issues of land rights and contract choice in section III, below.

There is an impressive literature on land tenure in southern Ghana (Gyasi 1994, Migot-Adholla and Place, Okali 1983, Rattray 1954, Robertson 1987). In contrast to some other parts of Africa, women in the study area do not gain access to land only through their husbands (although that is one path through which women do obtain land for cultivation). The inheritance of land is fundamentally conditioned by the matrilineality of the Akan who live in the study area. Succession to land, in principal, occurs within a matrilineage, with a nephew inheriting from his mother's brother. In fact, there is great variation in practice as the matrilineage elders have substantial scope for choosing the successor to a member of the family, taking into consideration personal achievements and involvement in family matters. Negotiation, therefore, plays a very important role in the allocation of land (Berry 1995) Both women and men can inherit control of family land in this matter. Moreover, temporary usufruct rights to land can be acquired directly by a women from her family without the involvement of her husband (Benin and Wilen 1996). In addition, land can be purchased by individuals (men or women), and their control over such land approaches the freehold ideal, with the exception that upon death it may become "family" land under the control of the lineage elders (Gyasi 1994). Finally, there are a variety of temporary rental or sharecropping arrangements through which an individual can gain access to land.

There is, therefore, a broad range of arrangements through which a particular individual can come to be cultivating a particular plot. This presents an opportunity to gain insight into the relationship between particular sets of rights over land and the choices made by the cultivator with respect to investments in that land. The complexity of tenurial arrangements also presents a problem, because it will be necessary to summarize land rights in a situation in which these rights are actively disputed. Our land tenure questionnaire (the Plot questionnaire in Appendix A) augments standard techniques which rely on an enumeration of rights (Migot-Adholla and Place) with a more flexible approach based on plot histories. This will facilitate the identification of the (possibly large) set of individuals who have various claims over a particular plot. Furthermore, the plot wrap-up questionnaire asked about intra-household disputes over crop yields even in cases where outside rights were clearly enumerated.

D. Contracts: Credit Markets, Contract Farming and Innovation

Fourth, decision making with regard to the adoption of technology and the management of land resources depends upon the characteristics of the markets, and in particular the capital markets available to farmers. The new technology of pineapple production requires substantially more working capital per hectare than does the established maize-cassava technology, and so participation in financial markets might be an important aspect of the adoption process. The management of soil fertility is an intertemporal allocation problem, and is therefore intimately related to each individual's position *vis-a-vis* capital markets. Pineapple production is also associated with more intensive use of hired labor, with the purchase of new types of inputs, and with an entirely new output marketing system tightly linked to consumer markets in Europe.

Land is a vessel: it is filled with nutrients, then those nutrients are extracted in the form of crops. This analogy (related by Marcel Fafchamps) is clearly understood by farmers in the study area. In informal interviews, some farmers explicitly argued that they were drawing down soil fertility in order to expand production. Mining the soil may be an optimal response to credit market imperfections. Decisions regarding the maintenance of soil fertility have an intertemporal dimension, so they are affected by the capital market environment within which farmers operate.

There are a variety of capital markets available to cultivators in the study area. There are some transactions with formal sector financial institutions, but these are relatively unimportant (less than 1 percent of gross borrowing by sample households came from formal sector institutions). About one-sixth of the farmers have saving accounts. Informal financial transactions occur mostly between family and friends. *Susu*[4] collectors, *susu* companies and specialized moneylenders exist, but play a quantitatively unimportant role. There is a good deal of credit from traders. There is also a degree of contract farming in pineapple cultivation, which contains a credit component. The structure of contracts in the study area, however, appears to differ from that found in other African contract farming schemes (Grosh 1992, Little and Watts 1994, Mackintosh 1989, Porter and Phillips-Howard 1995) because farmers in the study area claim that the contract only provides a guaranteed price, with virtually no credit (the only input provided by the exporter is a spraying of a forcing agent (NAA)). The main flow of finance runs in the other direction, with exporters paying farmers some weeks to a few months after collecting

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[4]Susu is an informal form of credit/savings.

the pineapple for export. The Borrowing, Borrowing Continuation, Lending and Lending Continuation questionnaires in Appendix A provide data on the flows of finance involving the sample households.

E. Policy Implications

The work initiated in this paper has a host of implications for policy design in the area of rural poverty, particularly the dynamics of crop adoption, the role of credit markets, the potential and dynamics of export agriculture, the gender division of labor and household income, as well as the design of targeting mechanisms.

Extension agencies in developing countries are constantly experimenting with new methods, attempting to develop a way to spread technology and techniques with a minimum of cost. In seeking to address the issue of who has adopted pineapple, we devote considerable attention to understanding the path of knowledge diffusion. As part of this, we are attempting to model a process that will be of great use to extension agencies as they take new discoveries to the field (see Conley and Udry 1999).   For example, we find that shared analysis through focal farmers and social networks plays an important role. An agency that understands these mechanisms will have greater success in reaching a greater number of farmers.

An understanding of the process of diffusion will also aid the government in identifying the complementary factors. Is wealth important? Education? This will enable governments to understand why some communities may have a slower rate of agricultural development than others and put into place broader policies to support the farmers. We also seek to identify who does not adopt the crop and why. This is even more critical, for these are people that either are excluded from the diffusion process or do not participate in a more profitable sector of agriculture for another reason. It may be that the imperative for government intervention here is strongest and extends beyond providing the complementarities to participating in the diffusion process.

It is important in this work that we develop a clear understanding of who can adopt but will not and distinguish those from others who would like to but can not. To do this we identify the potential constraints to adoption and examine to what extent they appear disproportionately in those not farming pineapple. We look at land rights and tenure, risk and insurance, land quality, access to labor markets, how farmers learn, and credit markets. Here this work provides direct insight into many policy areas. For example, one of the major arguments for the increased formalization of property rights is that this will allow greater investment in land as security increases. Some of those opposed to this policy argue that the traditional system of land management has provided for community management of natural resources and that this will collapse with private property rights. Through our examination of soil resource use and land tenure, we can hopefully shed some insight into how the multifaceted property rights in this area affect resource use and management. We will provide some insight into each of these policy areas, with particular reference to how they affect the adoption of new crops. The data itself is available for broader examination or to answer related questions.

One of our research questions is concerned expressly with what sets women apart in this farming system. The fact that so few women are engaged in what is a very profitable activity is alarming if the policy maker is concerned with increasing the adoption of export agricultural products and diversifying the country's economic base. If households operate as an efficient unit, this gender division might be simply due to intra-household specialization. However, in our observation of the communities, we did not see many non-married women engaging in pineapple production. As we examine the policy areas of land tenure, credit markets, and the like, we pay careful attention to the fact that these constraints may have a different impact on women. A better understanding of this will help identify a segment of the population that may need different types of intervention.   This research will also benefit broader social programs. As the understanding of the household and gender differences improves, policy makers can target social programs in areas such as education and health more effectively.

II Field Research

The research was conducted near Nsawam and Aburi in the Eastern Region of Ghana. Historically, the farming systems of the study area have undergone a series of significant changes. In the 19th century, oil palm production sparked the first inflow of migration to the area. This district was at the heart of Ghana's cocoa revolution at the turn of the 20th century (Hill, 1963). In 1930, swollen shoot disease devastated cocoa production and farmers adopted a system based on intercropped cassava and maize. Most recently (since the early 1990's), farmers in the area have moved towards intensive pineapple production for export.

The southern Ghanaian forest-savanna transition zone has seen a dramatic reduction in forest cover since the 1970s (the evidence is from aerial photography (Gyasi *et al*. 1994) and satellite imagery (Hawthorne and Abu-Juam 1995)), important reductions in fallow lengths over the same period (Gyasi *et al*. 1994, Amanor 1994), and increased evidence of soil deterioration and infestation by pests (particularly the virulent weed known locally as *akyeampong*) (Gyasi 1990; Amanor 1994). There is also evidence (Amanor 1994) that patterns of rainfall in the region have changed, but this is disputed by many geographers. The primary challenges in the transition to more intensive export crop production, according to the farmers and their extension agents, include managing the greatly increased financial demands of export pineapple production, and finding techniques which will maintain soil fertility under the new cropping system.

The methodology of the study is based on a simultaneous and interactive process of detailed observation, theory construction and statistical testing. Preliminary fieldwork and literature reviews led to preliminary models of the core economic issues associated with innovation and resource management in the changing farming system of the study area. This was an exercise in "old" institutional economics. The goal was to model individual incentives in the context of a given set of institutions, rather than to model the evolution of the institutions themselves. This preliminary modeling informed the development of the initial set of survey instruments. Results from the initial rounds of the survey led to changes in the preliminary models and to a need for modifications of the initial set of survey instruments. This can be seen most dramatically in the evolution of the questionnaires concerned with experimentation and social learning (Farm Information I and II, and Learning I and II in Appendix A) and intrahousehold relations (Marital Attitudes, Labor on Spouse's Plot, and Spousal Sales, as well as the intrahousehold components of most of the other questionnaires). In each case, responses to our initial questionnaires raised issues that led us to develop sequences of new survey instruments. Section III provides an illustration of this process as the reader can see some of the hypotheses we developed, gathered data on, rejected and then developed new ways to look at the issue.

The basis of the fieldwork is a series of interviews at approximately 6 week intervals with each of the survey participants over a two year period. The first year of the survey was directed by Udry; the second by Goldstein. Ernest Appiah of the Institute of Statistical, Social and Economic Research at the University of Ghana served as the field supervisor for the entire two year period of the project.

A fairly comprehensive set of individual and agronomic data is required to effectively address the core economic issues and thus the information requested from survey respondents is quite sensitive. As a consequence, we limited the size of the sample in order to maintain close oversight of the interview process. The sample was constructed in two stages. The process began with the purposive selection of villages in four clusters near the towns of Nsawam and Aburi. This region is the center of the recent growth of intensive vegetable cultivation in the Eastern Region. These four areas were selected due to their participation in the growth of fruit and vegetable production in the region, as well as their variety of agronomic, market access and geographic conditions. “Village 1" is a pair of adjacent villages 3 miles west of the large market town of Nsawam. Both villages were settled by Ashanti migrants during the 1850s. “Village 2" lies about 9 miles east of Nsawam and 4 miles southwest of Aburi on an old road joining the two large towns. It is made up of two towns, 150 and 80 years old that joined together 50 years ago. This village has the largest population of the four clusters with about 2030 people[5]. Five miles north of village 2 (and a 45 minute journey by vehicle) lies “Village 3". Village 3 is made up of a central town and two surrounding hamlets. The central town is fairly small (population is around 340) , and the youngest village, settled in 1939. People were farming this area long before, however, as one of the neighboring hamlets (pop. 110) was settled 200 years ago. With

[5] Population figures are calculated using the number of houses multiplied by the average household size (5.6)in our data adjusted for a joint occupancy rate of 37% (GSS, 1995) in this region.

limited access to non-farm income opportunities, village 3 is far and away the most agriculturally active community among the four. Two miles south of Aburi, and one mile from the road from Aburi to the capital of Accra is “Village 4". Settled in 1821, it has a population today of around 990 people. Twenty five years ago, cocoa farming was the major livelihood in village 4, and the village was fairly well off. Today no one is growing cocoa and farming has shifted to food crops. Despite this shift in agricultural income, the village has continued to grow, nearly doubling in size since the early 1970s[6].

The second stage of sampling was a random sample of married individuals in the villages. 60 couples (or triples, when there are two wives) were chosen by a simple random sample in each cluster, except in village 3, where we sampled all eligible households. This excludes single-person headed households from the sample (except in the case where they domiciled with a couple). This is not a trivial exclusion, as the Ghana Statistical Service points out, 29.6 of rural households are headed by women (GSS 1995)[7]. For much of the analysis, the level of observation is the individual (or the plot) which allows us to examine individual resources and behavior.

Two enumerators lived in or near each cluster of villages; a man who interviewed the men, and a woman who was responsible for interviewing the women. Given that we often asked them the couple to speculate on each other’s activities and resources, these interviews were private. In addition, another enumerator (actually, two who split the task) was responsible for

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[6]These histories are part of the village level questionnaires we conducted that also include social organizations, market infrastructure, and political and social organizations.

[7]This figure may be lower in this survey area because the proximity to Accra allows for migration to be less permanent.

administering the plot questionnaire and mapping each of the plots cultivated or owned by sample respondents. At the completion of each interview, the responses were checked by either Udry or Goldstein and questions returned to the enumerator for clarification and re-interview if necessary. Completed questionnaires were entered into the project database on a continuing basis.

The survey instruments and the timing of their application are listed in Appendix A. The data and questionnaires are being made available at http://www.econ.yale.edu/~udry/ghanadata.html. Some of the questionnaires are relatively minor modifications of standard survey instruments. However, even in these questionnaires there is additional attention to issues of intrahousehold allocation and resource flows. Other questionnaires are more innovative. Following is a brief description of the entire data set, organized by questionnaire.

Household Roster: This data was collected at the start of the survey and again after the first year. In the final round, a short update covering departures from and additions to the household during the second year of the survey was administered. Data on age, gender, education, occupation, migration and marital status were collected on all children ever borne to each wife, as well as on all current household members.

Soil Test - The two key outputs of the production process are current crop output and future land productivity. Estimates of annual changes in land fertility on individual plots can be provided by a pair of simple chemical tests. The key indicators of land fertility in the study area are soil pH and organic matter content (N and P are strongly correlated with these) (Gyasi et al 1994; Woomer et al 1994). Simple and inexpensive tests can provide estimates of these indicators (Lal 1977). We have collected two rounds of soil samples, and they have been analyzed at the soil science department of the University of Ghana.

Assets and *Trading Stocks* - Administered in three rounds, this gathered data on stocks of food, farm inputs, livestock, financial assets and participation in ROSCAs. The last two rounds of the assets questionnaire integrated the trading stocks questions. We discovered that we were not capturing all business assets, so the last round was modified in an attempt to achieve better coverage of these assets.

Output Sales and *Sales from Spouse's Plot* - These track the sale of output. Forward sales are recorded, as are the more common sales on consignment. In these cases, "continuation" forms follow the transaction until it is completed. In round 8 we began administering Sales from Spouse's Plot in order to better track the intrahousehold allocation of the proceeds from crop sales. This was implemented because we found that at times respondents would sell from their spouse's plot without their spouse's knowledge.

Plot Activities and *Work on Spouse's Plot* - The plot activities form provides the basic agricultural input and output data. Data on all labor and non-labor inputs and on all harvests from each plot cultivated by each respondent is requested. After it became clear that we were not achieving good coverage of the labor inputs by spouses on respondents' farms, we added the Work on Spouse's Plot questionnaire. This allowed for better information on the work by the spouse when the respondent was not present. Hired labor is linked to the individual roster discussed below.

Lending, Lending Continuation, Borrowing, and *Borrowing Continuation* - These questionnaires are based on tracking each loan from the point at which it is extended until it is either repaid or written-off. Data are collected on both contractual terms and actual payments, and on the use of any enforcement mechanisms. Borrowing and lending are linked to the individual roster discussed below.

Farm Information I - This set of questionnaires was designed to provide direct evidence regarding the flow of information between respondents. Motivated by conventional models of social learning, we asked for information about the farming of a random sample of other farmers in the village (randomly selected from those in our sample). We requested specific, verifiable information about operations, including chemical use, labor use, and output. This information can then be compared with the same information collected from the relevant farmers themselves. As discussed in section III.G below, we found that in almost all cases farmers were *not* able to provide this information. This led us to develop the following:

Farm Information II - Asked respondents about a series of specific innovations that they might have adopted over the previous year. In each case, we asked if they discussed the change with anyone, and if so, to identify the person. We were guided here by the hypothesis that social learning in this area occurs not by sharing data (on inputs and outputs), but rather by higher order conversations based on each others' working hypotheses regarding the matter of concern. The round 6 shocks questionnaire provides complementary information on discussions regarding unexpected shocks affecting plots. These two questionnaires provide a basic outline of the information sources available to respondents.

Learning - The two learning questionnaires build on this information. Learning I (agricultural learning) is a relatively unstructured questionnaire that aims to provide data on the sources of information peopled relied upon to begin farming, to deal with problems, and to adopt new crops, new seeds, or new chemicals. This questionnaire is linked to the individual and organizational rosters discussed below. In principle, this questionnaire yields a comprehensive list of all the individuals with whom the respondent has had significant conversations regarding agriculture, and all the organizations from which he/she has received significant advice. The problem, of course, is that different individuals have different notions of “significant”. The Learning II questionnaire is designed to mitigate this problem. It is based on matching the respondent with a random sample of six other respondents, and with two other village-specific “focal” individuals identified from the Learning I questionnaires as individuals in the villages from whom advice is commonly sought. Each respondent is asked about his/her relationship with each of these individuals, and whether or not he/she could approach the individual to deal with one of a set of specific agronomic and marketing issues.

Non-Farm Income - Non-farm income provides about half of the income of the sample respondents. Costs and revenues of the respondents’ non-farm enterprises are collected. In addition, this questionnaire records income from employment, from farms outside of the study area (many own, or have some rights over, land in other areas), and from miscellaneous sources such as inheritances or pensions. Respondents are also asked to estimate their spouses’ income from non-farm sources which, combined with a similar question on the sale of farm output, will allow us to see what spouses know about each others income.

Time Allocation - Collected at two different points in the farming cycle. Data is collected on time use over two 24 hour intervals. Respondents are also asked to estimate their spouses’ agricultural labor over the same period.

Gifts - Requests data on gifts received or given over the previous week, and on gifts received by or given to the spouse over the same period. Gifts are linked to the individual roster discussed below. In an effort to further explore transfers between spouses, we developed the marital transfers questionnaire which was asked for the last three rounds (in round 12 as part of marital II). This looks at most of the dimensions of spouse to spouse transfers as well as cash shortfalls and what alternative sources of funds were used. Respondents are also asked about transfer that their spouse has given and received.

Expenditure - The purchased food, food from own farm, and family expenses questionnaires constitute the expenditure survey. Repeated three times, this requests standard data on expenditures, but at the level of the individual rather than the household. In addition, respondents are asked about the expenditures of their spouse(s), and about the transfer of “chop money” - the primary spouse to spouse transfer.

Family Background - This provides information on the wealth of the respondents’ families, the respondents’ parents’ education and occupation, migration histories, the origins of the family, and inheritances.

Marital Attitudes I - These was a relatively open-ended questionnaires that attempted to measure the state of the marriage (trust, whether the spouse was working enough, etc), who in the household was responsible for different expenditures, and different dimensions of spouse to spouse transfers. There was also a brief marital history.

Marital Attitudes II - While less open-ended, this asked for greater detail about all previous spouses (e.g. formality of union, transfers), parents marital history, formality of the current union, and assets at time of marriage. It also contained the current marriage transfers component that was continued in the subsequent two rounds..

Plot Ranking - Respondents were asked to rank the fertility of their plots, and those of their spouse.

Shocks - An account of significant unexpected events which occurred on the plots of the respondent and his/her spouse. In rounds 6, 11 and 15 we collected data on any individuals with whom the respondent discussed the problems. This data is linked to the individual roster. Rounds 11 and 15 went beyond agricultural shocks and asked about illness and other unexpected events.

Plot Mapping - All of the plots were mapped using GPS equipment and GIS software.[8] This procedure yields much more accurate measures of plot size than are available in most surveys in developing countries. Moreover, by mapping the relative locations of all plots (and associated roads, paths and villages) it may be possible to distinguish between information transmission that is associated with social connections from that associated with geographical proximity. The mapping procedure opens the opportunity to investigate the importance of unobserved (and commonly unconsidered) spatial autocorrelation in production shocks. Finally, by accurately determining the location of each plot, it will be possible to match the agronomic and fertility data to medium-term historical information available from satellite photography and also to collect follow-up information indefinitely in the future. In association with the mapping, the Plot questionnaire was administered. This questionnaire begins with a simplified version of the plot rights questions developed for the Ghana Land Rights Survey (Migot-Adholla and Place), but is also concerned with the history of each plot. From the work of Berry (1993), it

[8]The mapping was conducted using a Trimble GeoExplorer GPS receiver and a Community Base Station for post-processing differential correction. This procedure results in accuracies in the 1 to 5 meter range.

seems possible that the path through which a particular farmer gained the right to cultivate a plot might be decisive in that farmer's effective rights over the land. The questionnaire also requests information on the current contractual status of the land, focusing in particular on the details of sharecropping contracts, which are very frequently used in the study area. Finally information on physical characteristics of the plot is collected. This includes a series of local indicators of land quality; these are based on local soil names. One potentially useful component of this project will be an examination of the correlation between these indigenous indicators of fertility and the results of the standard soil tests. We also collect cultivators' estimates of plot size. The results here are striking: the correlation between reported plot size and mapped plot size is only .15. Appendix graph 1 provides a plot of the relationship between reported and mapped plot size. Hill (1963) warned us about this. As a consequence of the agricultural history of the region, Akwapim field measurements are based on length rather than area - converting them to two dimensions as land has become more scarce has been difficult.

Plot Wrap-Up - This and other administrative questionnaires are used to keep track of new plots as well as dropped and fallowed plots. This final questionnaire requests data on the value of crops still standing as the survey ends and the property rights the spouse and children of the respondent would have if the respondent were to die.

Plot Status - This was combined with the events questionnaires in rounds 6 and 15. In addition to shock data, it asks what proportion of each crop belongs to the respondent, their spouse(s) and other claimants. In round 15 we asked respondents to provide this information not only on their plots, but their spouse's plots.

Individual and *Organization Rosters* - Data on the contacts that our respondents have with other individuals and organizations is recorded here. “Contacts” include learning interactions, credit and gift transactions, and labor market interactions. Data is recorded on the relationship and frequency of contact between the respondent and the contact, the residence and occupation of the contact, and the identification number of the contact if he/she is in the sample. Every contact has a unique identification number so we can trace them throughout the different questionnaires.

III. Adoption of New Technology: the Case of Pineapple

Evidence from the survey indicates that cultivation of pineapple is much more profitable than cultivation of any alternative crop. If this hypothesis is confirmed, it underlines the importance of understanding the adoption process. Why are only some cultivators obtaining these large profits? The remainder of this section provides the evidence that pineapple cultivation is substantially more profitable than alternative cropping activities, describes the distribution of the cultivation of pineapples across space and individuals, and begins the process of testing a number of alternative hypotheses regarding the determinants of adoption.

A. The Returns to Cultivation

The returns to cultivation are defined either as *profitability*, which is the value of output minus the cost of purchased inputs minus the value of family labor inputs (valued at current wages); or as *productivity*, which is the value of output minus the cost of purchased inputs. The former definition is appropriate if labor markets operate costlessly, while the latter is useful if family labor is supplied inelastically and cannot be used off the household’s farm. There are active labor markets in these villages, so most of the following analysis will focus on plot profits rather than productivity. However, it should be recognized that there are transaction costs and information asymmetries associated with hired labor in these villages, and that these market imperfections have implications for the definition of the returns from cultivation. These issues will be addressed in future work, as described below (section III.G). It does not appear that the choice of definition of the returns to cultivation has any important influence on the patterns discussed below.

Over the 18 months for which data are currently available, median profits per-hectare on plots planted to pineapple were approximately 1.5 million cedis, while median profits per-hectare for the sample overall were -115,731 cedis.[9] Median productivity per-hectare on pineapple plots was 2.3 million cedis, while for the sample overall it was 201,733 cedis. Table 1 shows that the difference in median profits per hectare between pineapple and other crops is extremely large (around 1.7 million cedis) after controlling for the village and gender of the plot owner. Note that at the five percent level, one cannot reject the hypothesis that men and women achieve equal profits per hectare once the differing cropping patterns of men and women are taken into account. Concentrating only on plots cultivated with pineapple, the final pair of columns provides weak evidence that women actually achieve higher profits than men in pineapple cultivation. To get a handle on the magnitude of these differences, note that the median size of plots in these villages is approximately one quarter hectare, and that individuals farm an average of about four plots. The 1.7 million cedi difference in median profits (over about 1 ½ years) generated by the choice to cultivate pineapple by an individual is roughly two and a half times Ghana’s per capita annual

[9]The $US - Cedi exchange rate moved over the period of the survey from approximately $1=1600 cedis to $1=2400 cedis.

GDP.

Measured profits are much higher on pineapple plots than on plots cultivated with any alternative crop. Is it possible that these measurements systematically overstate the profitability of pineapple relative to other crops? These calculations do not take into account the impact of pineapple cultivation on land fertility. It is possible, indeed likely, that the consequences of pineapple cultivation for the future productivity of the soil are different than the cultivation of other crops. Some of our respondents, in fact, state that they do not cultivate pineapple because it "chops the land". This issue is discussed in section III.C.

B. Who Cultivates Pineapple?

Pineapple is (virtually) not cultivated in one of the four study villages (see Table 2). Even in villages where significant pineapple farms are present, it is not ubiquitous. In no village are more than one-half of the plots cultivated with pineapple, and only in village 2 is pineapple the most commonly cultivated crop. Table 3 reports the striking result that almost no women cultivate pineapple. Almost 90 percent of the plots cultivated by women are devoted to cassava and/or maize, while only 55 percent of those cultivated by men are planted to these two crops. The first two columns of Table 4 combine these cross-tabulations, showing that after controlling for village, it remains the case that women are much less likely to plant pineapple than men. An understanding of the adoption process should provide an answer to the question of why so few women engage in the apparently highly profitable cultivation of pineapples.

C. Land Quality

It may be the case that only certain soils are suitable for the cultivation of pineapple. If so, then the distribution of pineapple cultivation may be determined in large part by the distribution of control over the various types of soil. It is certainly the case that geography is important: export pineapple simply cannot be grown in most of Ghana because most of its land area has inappropriate soil characteristics, rainfall patterns, or poor access to international markets. Table 5 documents the significant differences between the soil chemistry of plots cultivated with pineapple and with other crops for the three villages where pineapple is grown. Plots planted with pineapple are much more acidic and have much lower organic carbon content than plots planted with alternative crops. This might reflect cropping choices which match crops with appropriate soils - there is experimental evidence that pineapple flourishes in relatively acidic soil, and since it responds very well to chemical fertilizer treatment the organic carbon content of the soil may not be as important for pineapple as it is for other crops (Purseglove, 1972). Table 6 provides some evidence in support of this hypothesis: median per-hectare profits on pineapple plots appear to be increasing in the initial acidity of the soil and are unresponsive to the initial organic carbon content of the land; while for cassava and maize plots, per hectare profits appear to be increasing in the initial organic carbon content of the soil and are unaffected by the initial acidity of the soil. In each instance, however, the estimated coefficients are measured imprecisely and are not different from zero at conventional levels of significance. Soil chemistry appears to be related to crop choice: the third pair of columns in Table 4 shows that pineapple is likely to planted on plots which are more acidic, and perhaps on plots with a lower content of organic carbon.

Given the gender difference in cropping patterns it is worth looking at the gender difference in soil fertility. Women’s plots appear to be less fertile than those of men: the median organic matter[10] (OM) of maize/cassava plots cultivated by women is 3.10, while for men it is 3.38.[11] There is no significant difference in the pH of the maize/cassava plots cultivated by men and women. About half of the difference in the median OM of plots cultivated by men and women is accounted for by village effects. The remaining difference is 0.13 and statistically significant at the 10 percent level.

The rate at which fertility declines is lower on plots cultivated by women. The median decline in the pH of maize/cassava plots of women is identical to that of similar plots cultivated by men. However, the median decline in OM is lower on women's maize/cassava plots: -0.06 compared to -0.31 on men's maize/cassava plots[12]. Controlling for village effects, the difference is even more striking: the OM on men's maize/cassava plots declines much more rapidly than that on women's maize/cassava plots (the difference is 0.28 (p=0.07)).

Gender differences in fertility decline (though not initial fertility levels) persist even when we examine difference within households. Within households, the median OM Of maize/cassava plots cultivated by men and women are virtually the same (the difference is 0.03). However, the median decline in OM is much smaller on plots cultivated by women than on plots cultivated by their husbands (the difference is 0.33 (p=0.10)).

Given that these differences exist across genders, we need to ask if they play a role in the differential adoption of pineapple. The results in Table 4 seem to indicate that this is not the case. The addition of soil quality results in no substantive change in the probability that women

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[10]Organic matter is equal to a constant multiplied by organic carbon levels.

[11]The p-value of the null hypothesis that these medians are equal is 0.02

[12]The p-value of the null hypothesis that this difference is zero is 0.12.

will farm pineapple.

Figures 1-3 show the spatial distribution of pineapple plots in the three villages in which pineapple is grown. Even in areas with a high proportion of pineapple plots there are plots cultivated with maize and cassava, and pineapple plots also occur in isolation. There is no strong tendency for pineapple plots to be clustered: Tim Conley provides Figure 3.5, which shows that the distribution of distances between pineapple plots is similar to the distribution of distances between plots with other crops. It is not the case that crop choice is simply determined by location.

It is possible that the correlations between cropping patterns, plot profits, and soil chemistry are not a consequence of crop choice being affected by soil chemistry. There are important anthropogenic influences on soil acidity and organic carbon contact; in particular, crop choice itself might affect the evolution of soil's chemical properties. There is serial correlation in cropping patterns, so if pineapple tends to make the soil more acidic and reduces the organic carbon content of the soil, then the observed correlations may be a consequence, rather than a cause of the decision to plant pineapple on a particular plot. There is experimental evidence that pineapple does reduce soil pH (Collins 1960), which would compound the acidifying effect f the fertilizers currently used in its cultivation. Furthermore, the small amount of green manure remaining on pineapple plots after the harvest of fruit and planting material (suckers) would tend to reduce the content of organic carbon over time. We collected soil samples from each plot at the outset of the survey and one year later. It is possible, therefore, to monitor the changes in soil chemistry over that period. In contrast to our expectation, there is no evidence that pineapple cultivation had a more significant impact on the dynamics of soil fertility than the cultivation of other crops (see Table 7). Soil acidity increased over the year on all plots, but there was no significant difference between the change in soil pH on pineapple plots and on other plots. Similarly, the organic carbon content of soil on all plots declined over the year, but again there was no significant difference between the decline on pineapple plots and the decline on other plots.

Further work: There is no evidence in hand, therefore, to suggest that the observed differences in soil chemistry across plots planted to pineapple and those planted to other crops is caused by the differential impact of the different crops. However, there is additional work to be done before we can conclude that (a) adoption decisions are strongly influenced by soil characteristics and (b) that the impact of pineapple cultivation on soil fertility is not substantially different from the impact of the cultivation of other crops.

First, we collected data on the contractual arrangements through which land is acquired for cultivation. Included in this data is information on the cost of renting plots. Fixed rent contracts are not uncommon - about 20 percent of the plots for which we have this data - and they are disproportionately common for plots planted with pineapple. To the extent that pineapple cultivation has a different impact on soil fertility and hence future plot productivity, and that this impact is known, rents will be higher on plots to be used for pineapple. We have anecdotal evidence that this is indeed the case, but our data on rental costs is not yet ready for analysis.

Our data on contractual arrangements will also be useful in order to take into account the effect of tenurial status on cultivation decisions and hence on future land productivity. It is possible that individuals farming under different land contracts have different incentives regarding the future productivity of the land, and that their agronomic practices (such as weeding and chemical applications) differ accordingly. The relationship between crop choice and the dynamics of soil chemistry might be masked by a correlation between tenurial status and crop choice. We discuss the general patterns of tenure in the next section.

Finally, our more detailed land information contains data on the topography, visible soil characteristics, and crop and fallow histories of each plot. All of these characteristics interact with the initial chemical composition of the soil, agronomic practices and exogenous events (such as rainfall) to determine the time path of fertility.

D. Land Tenure

As indicated in the previous section, tenure is a fundamental factor in farm management. It is related to crop choice in two major ways. First, the type of crop a farmer proposes to plant may impact not only the type of contract that the landlord will offer, but the terms of that contract as well. Second, the farmer may also alter her crop choice based on the security of her tenure over a piece of land. It is a commonplace that increased uncertainty may lead the farmer away from crops with a long gestation period, but this is unlikely to be of primary importance in this farming system[13]. More importantly, different cropping choices have different implications for future fertility and hence future profits on securely-held land.

Men and women have different paths of access to land in this area. If we look at table 8 (Land rights and gender) we can see distribution of different rights that can be exercised exclusively by the respondent. Men are more likely to have every one of the rights we asked

[13]Of the main crops in this area, maize has the shortest gestation, pineapple can run to 18 months (with the harvest of the offshoot) and cassava about 2 years. Tree crops are ongoing with varying maturities, but they are relatively unimportant.

about, except for the right to sell and to mortgage. In the case of the right to sell, 23 percent of the female plot holders told us they could execute this right. This is probably due to the difference in the distribution of contracts by gender. Table 9 shows that the men are more likely to engage in cash rent than women, while women are more likely to get their land from the household than are men. The major source for both men and women is the family. This, combined with the matrilineal system of inheritance may account for the greater prevalence of the right to sell among female plot holders.

How does this influence the crop choice? At an initial glance rights do not appear to be different on pineapple plots than others. If we compare pineapple and non-pineapple plots, there is no significant difference[14] between the two cropping systems. However, if we look at the difference in rights by gender, there are some differences. Men who farm pineapple are significantly less likely (at 95 percent) to decide who inherits the pineapple plots than the non-pineapple plots. Women are more likely to have the right to sell, register or decide who inherits their pineapple plots than their non-pineapple plots (significant at 90 percent or better). This may suggest that the women who have been able to enter into pineapple farming possess more secure rights over the land.

Despite no marked difference in plot rights and crop choice, there are some differences in contract choice and crop rights. As we can see from Table 10 cash rent is much more prevalent among pineapple plots than non-pineapple farms. Non-pineapple farms, on the other hand, have a greater proportion of inherited land and allocated household land. The other major forms of contract, allocated family land and sharecropping, are equally represented in both cropping

[14]At the 95 percent level. At 90 percent, the decision to inherit is more prevalent on non-pineapple plots.

systems. However, it was often the case that, due to the greater cost of inputs, the terms of a pineapple sharecropping contract were different than those of other crops.

Further Work: It is clear that the contract choice is part of a dynamic relationship between soil fertility and crop choice. We need to develop a more comprehensive model that specifies the relationship and allows for these interactions. It also seems that the women who manage to start farming pineapple operate from a greater security of land tenure. However, many of the female pineapple plots are allocated household land (seven of the fifteen for which we have data). It is likely that the women who are starting pineapple cultivation are working closely with their husbands. We need to examine more closely the characteristics (such as wealth) of the women and also of the household (e.g. cooperation). Finally, we need to examine what happens to the proceeds of these plots. Even though the women retain the right to sell and harvest, it may be that these pineapple plots are given to the women with the idea that the proceeds will be used solely for the household.

E. Risk

At the core of many models of the adoption of new technology is risk and risk aversion. If insurance markets are incomplete, individuals might not adopt a profitable innovation if it would increase the risk they face. While it appears that the expected profits of pineapple cultivation are higher than the expected profits of the cultivation of alternative crops, it may be that including the cultivation of alternative crops in an individual's portfolio of activities reduces the risk they face, and thus remains optimal. It may even be that the cultivation of pineapple is so risky (and its minimum profitable scale of cultivation so large (see section III.F)) that for some individuals it is not optimal to cultivate pineapple at all.

Consider first the cross-sectional distribution of per-hectare profits. Figure 4 shows the remarkable finding that not only is the average profit from pineapple plots much higher than that of alternative crops, but that the cross-sectional distribution of pineapple profits first order stochastically dominates the distribution of profits from non-pineapple plots. In Figure 4, only the bottom 90 percent of the distributions are shown, because profits of the top 10 percent of pineapple plots are so large that the scale required to display them renders the remainder of the figure difficult to read. It is not evident from this cross-sectional data that planting pineapple poses a higher risk of a substantial loss than does planting any other crop.

The cross-sectional distribution of profits per hectare, of course, is only distantly related to the risk facing cultivators as they make their cropping decisions. It is possible, for example, that "other crops" are planted on a much more diverse set of plots than pineapple, leading to a broad range of realized profits even if deviation of realized profits from expected profits on any particular plot is small. A more direct measure of agricultural risk is available from data collected on the incidence of a set of problems that commonly affect farms in the area.[15] For each incident, respondents were asked to report a subjective measure of its severity, the proportion of the plot affected, and an estimate of the monetary damages (in very few cases were respondents able to respond to the latter). Table 11 shows that such shocks occurred on about 15 percent of the plots cultivated by respondents over the first year of the survey period. Plots cultivated with pineapple were somewhat less likely to be affected by these shocks than were

[15]The specific events for which incidence was solicited included: termite and other insect infestation, rodent (grasscutter) damage, "wilt" (which has multiple causes), loses from fungi or diseases, damage due to flooding or too little rain, and theft.

plots cultivated with other crops.

It is difficult to discern a strong relationship between the incidence of self-reported adverse shocks and per-hectare profits. Table 12 shows that, on average, per-hectare profits are lower on plots which are affected by an adverse shock. For pineapple plots, the estimate of this drop is huge (2 million cedis) but the standard error is just as large. For other plots, the sizable drop (almost 400,000 cedis) is estimated more precisely. Changes in median profits associated with the incidence of shocks, however, are more ambiguous. There is no significant difference in median profits between plots affected by a shock and those for which there is no shock for either pineapple or non-pineapple plots. These results are broadly similar for more full specifications of the profit functions including village and gender dummy variables.

There are a number of difficulties associated with the use of measures of self-reported shocks which may be the source of these mixed results. Probably most important is systematic reporting bias in which the measurement error in the self-reported shock variable is correlated with an unobserved characteristic of the plot (perhaps the plot owner's attentiveness to his or her farms) which is itself correlated with per-hectare profits. Further work is planned which will use our more detailed information on the particular events which occurred on our respondents' farms to try and address this problem.

It may be the case that these measures of shocks miss an important set of random events which affect pineapple more severely than other crops. Several of our respondents claimed that the choice to plant pineapple entailed the acceptance of an important marketing risk. Pineapples are cultivated for the export market. Occasionally, at the time of harvest it is impossible to sell the crop to an exporter. In some cases the exporter rejects all or part of the crop because it does not fit the size and quality requirements of the export market; in others, confusion or poor communications between the farmer and possible exporters result in a missed export opportunities. In these instances, the crop must be sold at a much lower price on the limited local market. Such shocks occurred on more than ten percent of pineapple plots, with a median cost per hectare of almost 400,000 cedis per incident (recall that median profits per hectare for pineapple are about 1.5 million cedis).[16] This, apparently, is a significant source of additional risk faced by those who chose to cultivate pineapple. It is quite puzzling to find that median profits per hectare are far higher on plots subject to this sort of marketing shock than on other pineapple plots (see Table 12).

None of these measures, even in principle, correctly summarizes the risk faced by a farmer contemplating adopting pineapple. First, there is an important aggregate price risk faced by cultivators selling on a world market that cannot be identified in this cross-sectional data. Second, in a small sample the full distribution of the production shock is difficult to estimate, and there is a particular worry that cultivators' decisions depend on low probability but high cost events which do not occur in the sample. Finally, pineapple is a new crop and an important component of the overall risk might be cultivators' uncertainty about the underlying technology. This is addressed in section III.H.

These caveats aside, we have found no convincing evidence that the failure of most women and many men to adopt the apparently highly profitable technology of pineapple cultivation is driven by considerations of production risk.

Further work: The self-reported measures of both production and marketing shocks can

[16] We have no measure of similar shocks on non-pineapple plots, but they would be negligible.

improved using data on the details of reported production shocks and on the sales of pineapple to local traders. In addition to these farm-based measures, there is data on shocks to health, non-farm income, and wealth. With improved measures of shocks in hand, future work on the consequences of risk will use our series of three expenditure surveys of the respondents. Is there a relationship between the realization of shocks and the evolution of consumption? Evidence on aggregate price risk can be drawn from the time-series of pineapple prices.

F. Capital Constraints

The virtually unanimous response to the question "Why are you not farming pineapple?" provided by our respondents was "I don't have the money." There is reason to be suspicious of such responses when they come in reply to questions in a formal survey (some respondents surely hope that the researchers might be able to arrange for a subsidized credit program, for example). Nevertheless, the claim has merit on its face. Successful cultivation of pineapple demands far more intensive use of purchased inputs, including planting materials, chemicals, and labor than does the cultivation of alternative crops. Moreover, exporters purchase entire plots for export, and will not deal with plots below a certain minimum size. Finally, the middle two columns of Table 4 provide evidence that it is the wealthy who tend to cultivate pineapple, a fact that is evident to our respondents. In this section, I examine the hypothesis that some individuals do not adopt pineapple because they have difficulty raising capital to fund this otherwise profitable venture.

Figure 5 shows an estimate of the density of plot sizes for pineapple and other crops. Plots devoted to pineapple do tend to be substantially larger than other plots. For the sample as a whole the median plot size is approximately one-quarter hectare, while the median size of pineapple plots is approximately .4 hectares. Is this a consequence of a larger minimum economically-viable plot size for pineapple than for other crops? Figure 6 provides non-parametric estimates of the relationships between profit and plot size for pineapples and for cassava/maize mixtures. Profits on pineapple plots are higher than on cassava/maize plots at all plot sizes. In both cases, profits per hectare are inversely related plot size throughout the distribution of plot sizes. This figure provides no empirical support for the notion that there is a minimum scale necessary for profitable adoption of pineapple.

Pineapple costs much more to produce than other crops. The median cost of non-labor inputs per hectare for pineapples is 112,000 cedis, while for cassava and maize it is 10,000 cedis. Including the cost of labor inputs narrows the gap, but it remains large: for pineapple the median total cost per hectare of inputs is about 1 million cedis, and for cassava and maize it is 600,000 cedis. Table 13 provides a comparison of mean input costs on cassava/maize and pineapple plots. Median costs per hectare are examined in Table 14, where evidence is provided that pineapple plots have much higher costs than other plots in a more rich specification of the cost function. There is weak evidence in Table 14 that women use non-labor inputs less intensively than men, and that labor inputs are used less intensively on larger plots than on smaller plots.

If we suppose (contrary to Figure 6) that the minimum size of a pineapple plot is about one quarter hectare, then the estimates reported in Table 14 imply that a new pineapple plot would cost about 175,000 cedis. This is a substantial sum - about 25 percent of per capita GDP in Ghana. Is this the primary barrier to entry into pineapple cultivation? Is this also the reason for the observed correlation between wealth and pineapple cultivation?

The high cost of farming pineapple relative to its alternatives, coupled with the dependence of pineapple farmers on exporters to access to European markets and the need for precise timing between harvest and the final sale of the fresh pineapple to consumers creates an environment in which it might be expected that contract farming would flourish. Exporters (or large scale pineapple farmers who also export the crop) could provide credit to cultivators, with the standing crop serving as collateral for the loan. Surprisingly, this type of contract is very rare. Over the first year and a half of the survey, only four loans (out of over 1,100 recorded) were made by exporters to cultivators in our sample. The flow of finance is actually in the other direction, as it is very common for cultivators to provide pineapples on consignment to the exporter, with payment for the crop being received by the farmer only several weeks or months after harvest.

The surprising absence of a well-developed system of contract farming need not inhibit adoption if potential cultivators have good alternative access to financial markets.   Preliminary analysis indicates that credit markets in the survey villages are active and surprisingly well-integrated into larger markets. 312 of 425 respondents borrowed over the first year and a half of the survey, and the total amount that they borrowed (summed over the entire period) averages (over the individuals) 170,000 cedis. Median borrowing is less at about 60,000 cedis, but the 80th percentile of the distribution of gross borrowing is over 175,000 cedis. Moreover, a remarkably high proportion - 72 percent - of gross borrowing originated from outside the village of the borrower. The scale of borrowing, at least, is such that it raises the possibility that individuals might be able to finance new pineapple cultivation through credit markets.

There is a dramatic difference, however, in the borrowing activities of men and women. Table 15 provides summary statistics on borrowing by gender. A higher proportion of the value of borrowing by men originates from outside the village, and the absolute amount borrowed by men is far larger. Median borrowing by men is 100,000, while for women it is under 40,000. Perhaps this differential participation in the credit market is part of the explanation for the gender difference in rates of adoption of pineapple.

If the large minimal cost of cultivating pineapple is an important barrier to adoption, then the farmer's own financial resources will play a role in the adoption process. We saw in Table 4 that a cultivator's current wealth is correlated with the probability that he is cultivating pineapple. However, we cannot conclude from this that credit constraints are important for adoption decisions. This correlation may be a consequence of the fact that pineapple profits generate wealth for the owner, or a consequence of a correlation between current wealth and an unobserved characteristic of the plot or its cultivator that is correlated with the likelihood that pineapple will be planted. The relationship between cultivator wealth and the adoption of pineapple is estimated again in Table 16, with current wealth treated as endogenous. The results are striking. In the linear probability model, variation in wealth (treated as endogenous and instrumented with the parental background variables listed in Table 17) is very strongly related to adoption of pineapple. Plots cultivated by individuals predicted to have an additional one million cedis of wealth (less than one standard deviation in the wealth distribution) are eight percentage points more likely to be planted with pineapple. The point estimate in the probit specification (which has been converted to have an analogous interpretation) is somewhat lower and is estimated with less precision.

The instrument set for wealth includes: the cultivator's parents' educations and occupations, the number of wives of the cultivator's father, the cultivator's mothers marriage parity, and indicators if the cultivator holds a hereditary office or has received particular kinds of inheritances from his or her family. The first stage regression is reported in Table 17. The identifying instruments are highly significant predictors of current wealth. The structure of the cultivator's parents' marriage, parents' occupations, family migration history, and holding of an hereditary office are particularly important determinants of current wealth.[17]

The results so far, therefore, provide mixed support for the notion that credit constraints play an important role in the adoption process. Pineapple is certainly more costly to produce than alternative crops, and exogenous variation in wealth is strongly and statistically significantly (in some specifications) positively correlated with the cultivation of pineapple. However, it is difficult to observe an economically meaningful minimal plot size required for the profitable cultivation of pineapple. Nor does exogenous variation in wealth contribute to explaining any of the gender differential in adoption rates. Restricting attention to cultivators who are women, it remains the case that exogenous variation in wealth is uncorrelated with the adoption of pineapple. This is particularly surprising given the minimal participation in credit markets by women.

Further work: The current probit instrumental variable estimator is misspecified. It relies on the untested assumptions that the errors on the probit equation and the instrumenting equation are jointly normal and homoskedastic. Moreover, the standard errors on the probit are underestimated in the current specification, which does not account for the first stage sampling error. Unfortunately, there is no generally available semi-parametric alternative to this

[17]There is a potential problem with using the indicator of hereditary office as an instrument, because in some cases the receipt of such titles is negotiated. The success of the negotiations might depend on current wealth. The results, however, are virtually unchanged when this instrument is dropped.

specification. However, an estimator that explicitly incorporates heteroskedasticity can be implemented. This could help in disentangling the direct effect of gender on adoption from its indirect effect via wealth.

The credit market needs further investigation. Men and women have very different levels of participation in borrowing, and yet in neither case does instrumented wealth correlate with the adoption of pineapple. The next steps will be to examine the terms of borrowing as well as participation on the lending side of the credit market. In particular, the timing of borrowing will be compared with the timing to cultivation operations to examine the use of credit transactions for smoothing working capital expenditures over the crop cycle.

It is also possible to use indirect methods to examine the possibility that credit constraints are affecting the process of adoption. There is panel data (in three waves) on individual consumption expenditure. This can be combined with our data on income to check for evidence of incomplete consumption smoothing. Any such evidence can in turn can be related to cultivation decisions, with particular attention to gender differences in these patterns (Zeldes, Morduch).

G. Labor

One explanation for the domination of pineapple cultivation by men offered by some of our respondents is that the physical tasks involved in pineapple cultivation are unsuited to women. In some instances it was claimed that it was simply too much work; in others it was the type of work that was required that was problematic for women. We can dismiss the first explanation, but the second might require further exploration.

Table 18 shows that less of the cultivator’s own labor is used per-hectare on pineapple plots than on plots cultivated with other crops. At the same time, women use significantly more of their own labor per hectare on their own plots than do men. It does not seem likely that the pure quantity of labor needed to cultivate pineapple is excluding women from adopting.

A much higher proportion of the labor used on pineapple plots is hired labor (see Table 18), and women tend to use a smaller proportion of hired labor on their plots than do men. It might not be the work itself that is a barrier to entry by women into pineapple cultivation, but rather the transaction costs facing women hiring the large quantity of labor required for growing pineapple. Moreover, the final column of Table 18 shows that the hired labor used on pineapple plots is overwhelmingly male. In particular, the task of weeding pineapple plots seems to be reserved almost exclusively for men. On their own plots, women hire a much smaller proportion of male workers than do men. These results raise the possibility that women face higher transaction costs in hiring male workers than do men, and that this difference contributes to the much lower rate of adoption of pineapple by women.

Further work: A much more careful examination of the operation of the labor market will be required to test this hypothesis. There is information on the contractual arrangements through which each hired worker on a farm was engaged, the task they performed, the amount paid and the number of hours worked. In addition, for the last several rounds, we have a rich set of information on the relationships between the farm operator and the worker. Variation across genders in the contracts used for labor, in the cost of labor, and in the productivity of the labor on the farm will help identify differences in transaction costs. An additional potentially valuable source of information is our data on the non-farm enterprises in which women are intensively engaged, which includes information on the use of hired labor in the enterprises.

H. Learning

Large scale production of pineapple for export is a new innovation in these villages. Individuals may not know with certainty the technology of pineapple production. The uncertainty may be focused on the profitability of the new crop (e.g. Besley and Case, Mushi) or on the optimal timing or level of inputs (Foster and Rosenzweig). It might also be the case that making marketing arrangements for pineapple requires specialized knowledge - for the time being we treat this as a special case of the problem of learning discussed here.

Previous studies have traced the pattern of adoption of new technologies in order to investigate the importance of "social learning" and the associated externalities. It is not sensible, of course, to use the much smaller data set generated by this project to replicate these procedures. The primary identification problem of the previous studies is to differentiate social learning from the effect of unobserved variables that may be spatially and serially correlated and that effect the profitability of the technology under consideration. The advantage of this intensive survey is that we were able to ask questions which may make it possible to deal quite effectively with this identification problem.

The advantage of that we have is our ability to collect direct data on the flow of information between farmers. Given such data, the next step is to test if this information flow influences behavior. The goal will be to relate changes in a farmer's cultivation decisions and the profitability of his/her farm to the information that he or she receives from other farmers at earlier points in time. Strong evidence of social learning will be provided, for example, if it can be shown that the input intensity chosen by farmer X is affected by the input use and outcomes of other farmers when X has received advice from those farmers, and not by the input use and outcomes of other farmers with weaker informational linkages to farmer X.

The first step is to document and verify the flow of information between farmers. Results from the Information I questionnaire provide strong evidence that the model of learning commonly used in the economics literature is inappropriate in this area. In less than 2 percent of the instances in which we asked someone about activities on another farmer's plot was our respondent able to report the specific quantities of chemical inputs used. In less than half of these instances was our respondent's guess within 50 percent of the actual quantities of chemical used by the other farmer. In almost each case of a "near miss", the two farmers were close relatives. Our preliminary evidence, therefore, is that farmers in these villages do *not* learn by sharing data in line with the standard model. Rather, to the extent that social learning occurs, it must be based on sharing *analysis* rather than data. That is, farmers learn from their own experiments, draw conclusions, and then share these conclusions with each other. It this type of learning is occurring, it requires both different theoretical tools of analysis and an innovative form of data collection.

Further work: The surprising results concerning respondents' knowledge of other farmers' activities led us to collect further data on information networks and learning. Two complementary types of data seem particularly promising. The first is drawn from the listing of individuals with whom our respondents report having significant learning interactions (the Learning I questionnaire). The pairs defined by our respondent and each of the individuals on his/her listing are informational links. Combining this information over the whole sample yields a fragment of the village-wide information network (the complete network is not defined by this data, because we know nothing of links between any two individuals not in our sample). The major problem with this data is the varying definitions of “significant learning interaction” used by the different respondents.

The second source of data is drawn from random matches of individuals within our sample in the Learning II questionnaire. We matched each respondent with six randomly selected respondents in the same village, and also with two village-specific individuals who from external information appear likely to serve as nodes in information networks. A series of structured questions yields data on the intensity of the interaction between these randomly matched pairs. This data provides a second estimate of the configuration of the information networks in the villages.

The current plan is to first compare these estimates of learning interactions with (a) spatial information on the distribution of plots and houses; (b) information on family, clan and church membership; and (c) data on interactions in the credit and labor markets and on gift exchange. Can the data on information exchange be distinguished from these other indicators of social interaction? If so, it will be possible to move to the next stage of the research, which will be to relate correlations in profitability, crop choice, and input choice to the data on information exchange. If there is evidence that the cultivation choices of individuals tightly linked through the information network are correlated, then it will be appropriate to use the panel aspect of the data to see if *changes* in cultivation practices are more strongly influenced by news arriving through the information network. This will provide a test of the hypothesis that social learning is an important element in the diffusion of the new technologies of pineapple production through these villages.

IV. Conclusion

This paper has taken an initial look at the question of what distinguishes adopters and non-adopters of pineapple in Southern Ghana. We started from the assumption that the factors that separated female non-adopters and male non-adopters were different. In our examination of various factors such as credit, land tenure, and soil quality we have seen marked differences in males and females. These are differences that stem from another process than that which separates the male adopters from the non-adopters.

To understand the process of adoption the analysis needs to proceed in two directions. First, a more rich model of the learning and diffusion process needs to be developed and tested. Pineapple is a complex crop, it involves extensive and varied chemical inputs, it is sensitive to variations in soil, and it requires careful husbandry to produce export quality fruit. These techniques exist in three of the villages. When we understand how they move through the male population we will have a better understanding of how agricultural policy ought to be made. Within the household, it appears that another process may be at work. This paper offers consistent evidence of cross-gender differences, but no indication that these differences are not a manifestation of efficient household decisions (and hence in the best interest of the household as a whole). Indeed, we need to examine how the household functions as a "whole". We need to test for household efficiency in production. In the absence of efficiency, the differences in resources becomes a critical issue in the welfare of women and their ability to participate in the agricultural sector. Should we find efficiency, the best level of analysis may turn out to be the household. Considering the household as a whole, we can examine the household, as well as individual characteristics that affect adoption.

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Table 1 : Determinants of Profit/Hectare (x1000 cedis)

LAD Regressions

	All Plots				Pineapple Plots only	
	estimate	t-ratio	estimate	t-ratio	estimate	t-ratio
female owner	-121.44	-2.17	-97.20	-1.33	2232.89	1.48
village 2			-32.87	-0.33	2343.38	2.20
village 3			-107.50	-1.36	824.77	0.78
village 4			-79.14	-0.99		
cassava/maize			-52.62	-0.64		
pineapple			1691.55	15.66		
constant	-79.78	-3.14	-18.53	-0.24		
	539 observations				122 observations	

Table 2: Distribution of Primary Crops across Villages

	village				
crop	1	2	3	4	Total
cassava	66	58	155	145	424
	27.62	31.52	40.36	55.34	39.66
palm	29	1	2	2	34
	12.13	0.54	0.52	0.76	3.18
maize	88	33	117	63	301
	36.82	17.93	30.47	24.05	28.16
plantain	12	3	1	7	23
	5.02	1.63	0.26	2.67	2.15
pineapple	14	81	94	1	190
	5.86	44.02	24.48	0.38	17.77
other	30	8	15	44	97
	12.55	4.35	3.91	16.79	9.07
Total	239	184	384	262	1069
	100	100	100	100	100

Chi2(15) = 318, p = 0.00

Table 3: Distribution of Primary Crop across Plots by Gender of Owner

crop	gender 0	1	Total
cassava	225	199	424
	30.86	58.36	39.63
palm	34	1	35
	4.66	0.29	3.27
maize	195	106	301
	26.75	31.09	28.13
plaintain	18	5	23
	2.47	1.47	2.15
pineapple	178	12	190
	24.42	3.52	17.76
other	79	18	97
	10.84	5.28	9.07
Total	729	341	1070
	100	100	100

chi2(5)=126, p=0.00

Table 4: Probit Estimates of the Determinants of Pineapple Cultivation

Coefficient	Change in P(pine)	z	Change in P(pine)	z	Change in P(pine)	z
village 2	0.38	8.97	0.21	5.98	0.226	4.27
village 3	0.19	6.78	0.07	3.62	0.184	4.36
village 4	-0.11	-2.97	-0.13	-4.25	-0.151	-3.32
gender of owner	-0.14	-8.46	-0.12	-7.55	-0.166	-7.01
wealth			0.01	2.16		
pH					-0.088	-5.75
oc					-0.026	-1.73

notes: overall P(pine)=.150
Change in P(.) for dummy variables = P(pine|1,x)-P(pine|0,x), where x is the mean of the remaining RHS variables.

Table 5: Soil Chemistry on Pineapple and non-Pineapple Plots

	Organic Carbon	pH
Pineapple Plots	1.62	5.89
Non-Pineapple	2.00	6.59
t	5.03	10.53

t refers to the t-statistic for the test of H_0: mean(non-pineapple) - mean(pineapple) = 0

Table 6: Impact of Soil Chemistry on Per-Hectare Profits (x 1000 cedis)

	Pineapple Plots		Non-Pineapple Plots	
	estimate	t	estimate	t
village 2	-1280.98	-1.089	-180.008	-1.265
village 3	-2535.93	-2.224	-62.1126	-0.591
village 4			6.908582	0.069
oc	197.0245	0.531	90.22267	1.658
ph	-650.957	-1.437	44.12483	0.686

LAD regressions, t calculated from bootstrapped standard errors

Table 7: Changes in Soil Chemistry over the Period 12/96-12/97

	Organic Carbon	pH
Pineapple Plots	-0.12	-0.24
Non-Pineapple Plots	-0.15	-0.30
t	0.41	0.76

Table 8: Land Rights and Gender
percent of gender group holding rights

				# of observed plots	
Land Right	Male	Female	Difference	male	female
Decide to rent	41.7	19.2	22.4**	585	213
Decision to lend	48.0	33.0	15.0**	585	212
Right to mortgage	34.8	30.2	4.6	584	212
Right to pledge land	40.1	32.4	7.7**	584	210
Right to sell	16.4	23.2	6.8**	586	211
Can register land	26.7	24.6	2.1	580	211
Decide inheritor	13.2	7.0	6.2**	583	213
Make harvest decision	98.2	94.3	3.9**	829	296
Sell crop decision	98.7	95.5	3.1**	828	292

** indicates difference significant at 95 percent

Table 9: Gender and Contract Type percent of within group plots under contract		
Contract	Men	Women
Inherited	4.3	4.1
Allocated family land	50.1	46.0
Allocated household land	2.7	21.6
Allocated village land	0	1.0
Purchased	0.9	0
Gift	0.8	0.6
Caretaker	1.4	0.6
Cash rent	22.1	13.3
Sharecrop	14.9	11.3
Loan (no specified repayment)	1.1	0.6
Other	0.1	0.3
Rented out	1.1	0.3
number of observed plots	931	315

Table 10: Crop Choice and Contract Type percent of within group plots under contract		
Contract	non-pineapple	pineapple
Inherited	4%	2%
Allocated family land	51	50
Allocated household land	9	4
Allocated village land	0	0
Purchased	1	1
Gift	1	0
Caretaker	1	1
Cash rent	17	26
Sharecrop	13	14
Loan (no specified repayment)	1	0
Other	0	0
Rented out	1	1
number of observed plots	745	241

Table 11: Incidence of Adverse Shocks of Greater than "Minor" Severity

	No Shock	Shock
Pineapple Plots	172	18
	90.53	9.47
Non-Pineapple Plots	746	134
	84.77	15.23

chi2(1) = 4.24, p=0.04

Table 12: Impact of Adverse Shocks on Per-Hectare Profit

	Mean Profit per Hectare		Median Profit per Hectare		Pineapple Plots Only Median Profit per Hectare
	Pineapple	Non-Pineapple	Pineapple	Non-Pineapple	Shocks are Marketing Shocks
Adverse Shock	1411	-538	1866	-208	4488
No Adverse Shock	3403	-155	1421	-109	1377
t-test of difference	1.24	2.05	-0.32	1.172	3.77

Table 13: Mean Per-Hectare Costs on Pineapple and Maize/Cassava Plots

	Non-Labor Inputs x 1000 cedis	All Inputs x1000 cedis
Pineapple Plots	413	1278
Maize/Cassava Plots	127	1040
t-test of difference	-4.22	-1.58

Table 14: Median Costs per Hectare on Plots Planted to Different Crops (X 1000 cedis)

	Non-Labor Costs		All Costs	
	coefficient	t	coefficient	t
village 2	-17.36	-1.83	-187.53	-2.01
village 3	-9.66	-1.25	-123.87	-1.23
village 4	22.41	1.28	199.32	2.28
Pineapple plots	104.44	1.91	703.46	5.09
Cassava/Maize plots	4.93	0.38	58.90	0.54
hectares	-3.57	-0.65	-388.71	-4.30
gender of cultivator	-10.59	-1.62	-81.33	-1.00
constant	17.75	1.35	707.68	6.35

LAD Regressions, 559 Observations, bootstrap standard errors

Table 15: Borrowing by Gender

	mean x 1000 cedis	median x1000 cedis	proportion borrowed from outside the village
Men	296	100	.75
Women	73	37	.63
t-test of difference	2.89	4.17	

Table 16: Estimates of the Determinants of Pineapple Cultivation

	Probit Model		Linear Probability Model	
Coefficient	Change in P(pine)	z	coefficient	z
village 2	0.46	5.02	0.36	4.63
village 3	0.28	4.92	0.14	2.96
gender	-0.26	-4.69	-0.17	-3.40
wealth*	0.06	1.42	0.08	2.18

notes: overall P(pine)=.28, village 4 excluded
Change in P(.) for dummy variables = P(pine|1,x)-P(pine|0,x), where x is the mean of the remaining RHS variables.
*Wealth treated as endogenous. Instruments for wealth listed in Table 17

Table 17: First Stage Regression - Predicting Current Wealth

	coefficient	t
cult. first of family in village?	-13672.1	-0.142
cult. holds hereditary office?	438854.3	5.377
# of father's wives	181483.6	5.849
# of father's kids	223.6752	0.04
parity of mother in father's marriages	-180401	-3.596
cult. ever a foster child?	18796.87	0.282
received land inheritance?	37400.2	0.318
anticipates a land inheritance?	-347192	-2.567
received other inheritance?	-76680.1	-0.698
received other assistance from family at marriage?	22533.57	0.276
mother was a trader	-135416	-1.447
mother was neither trader nor farmer	-439609	-2.384
father was an artisan	40298.01	0.328
father was a civil servant	265768.5	2.095
mother had low (positive) level of schooling	-98411.5	-0.607
mother had high level of schooling	39349.67	0.243
father had low (positive) level of schooling	-195735	-1.61
father had high level of schooling	863.9733	0.009
years the family has resided in village	4103.22	3.454
family from volta region	-37883.5	-0.297
family from outside Ghana	-201322	-1.334
village 2	656061.3	5.747
village 3	382889	3.657
village 4	223874.6	2.014
gender	-439832	-5.774
constant	245963.4	1.922

Test of identifying variables $\neq 0$: $F(21,1144) = 7.96$ $p=0.00$
Overall test of significance: $F(25,1144)=12.18$ $p=0.00$

Table 18:
Labor Use on Pineapple/Other Plots, and on Plots Cultivated by Men/Women

	Mean Hours of Work per Hectare		Proportion of Labor that is Hired		Proportion of Hired Labor that is Female	
	mean	t-test of difference	mean	t-test of difference	mean	t-test of difference
Pineapple Plots	442	1.77	.54	-16.73	.12	3.86
Non-Pineapple Plots	661		.17		.35	
Men	517	-2.68	.30	10.15	.25	-3.39
Women	796		.13		.42	