Developing World III: Land Trade and Development

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These notes are based off a presentation by Professor Gharad Bryan for the section on the developing world in the Mechanism Design for Social Good Reading Group. The notes are taken by members of the reading group with some figures and texts taken from presentation and paper [2]. Questions and comments from reading group members during the presentation are labeled as such. The reading group organizers take full responsibility for the notes. Please contact the organizers with any questions or comments.

1 Introduction

We will give an overview of how land markets and agricultural activities work in developing countries. This will suggest that land trade land might be useful for increasing agricultural productivity. Low agricultural productivity is one of the key reasons why developing nations stay poor. There is high correlation between agricultural productivity and development. Both farmers and land vary in productivity. High productivity land is not always assigned to high productivity farmers. Land market failures are a possible cause of low agricultural productivity. *Why are naturally occurring markets slow at reallocating land from low productivity farmers to high productivity farmers?* We will discuss what the theory suggests.

We will talk about what sort of market design might do well at improving the quality of land allocations. The problem with applying market design in this context is that presumably it is difficult for farmers to understand these complex processes. The accompanying paper is asking the simple question of whether we can get farmers in these developing nations to understand the rules of these simple combinatorial auctions [2]. The broad finding is that most farmers do, in fact, cope well with the auction, which suggests that it is plausible that more complex market design can play a role in land trade in developing countries.

2 Land and Agriculture in the Developing World

Agricultural land in developing nations is often *small and fragmented.* In developed nations such as the United States or Canada, you often have a few families that own very large farms. In developing nations, on the other hand, you have a much larger number of families who own smaller plots of farms.

In addition to being small, farms are also fragmented. There are many plots of land and the distance between them is also substantial. For instance, the average farmer in Rwanda has five plots of land and the average size is 0.8 hectors.

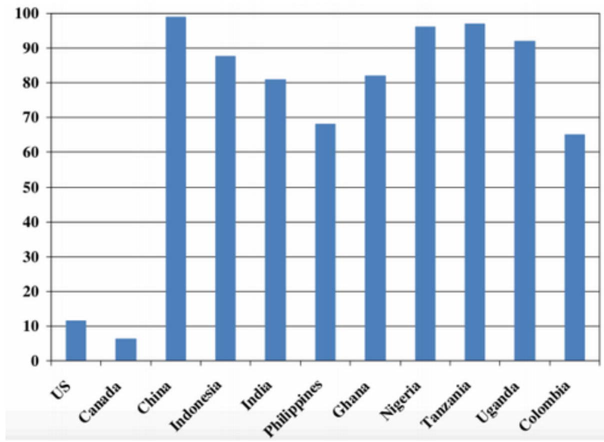


Figure 1: Percent of Households with Operational Landholding Below 10 Acres, by Country [3]

Small fragments lead to inefficiency in farming technology used. Technology the produces the most output per hour cannot be used on small fragments.

Figure 2: % of Households with Operational Landholding Below 10 Acres, by Country [3]

There is evidence of this technological increasing returns to scale.

Figure 3 picture shows that as we increase land size, productivity dips slightly before going up again. There are various theories including: for smaller land sizes, you can farm using just family labor. As the size goes up, you have to hire outside labor and supervise them. Initially you may only want to hire just half a day labor, but you would have to pay for a full day. Outside laborers may not incentivized to work as hard as family labor.

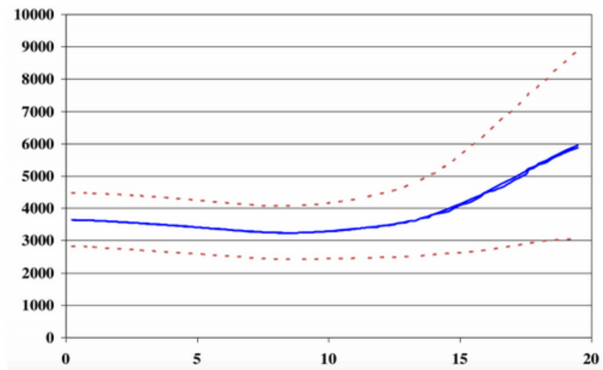


Figure 3: LWFCM Estimates of the Effects of Land Size on Profits with 95% CI, Net of Soil Quality and Time/Village Fixed Effects, by Farm Size [3]

There are reasons to believe why small and fragmented plots may be an (in)efficient. If we focus on efficiency:

- It is known that family labor is easy to motivate and this suggests that you may want to have small farms that you can maintain with just your family. Having larger farms would require hiring labor, and these workers might be less productive than family members.
- In terms of fragmentation, if you do not have access to insurance markets, then you may want to scatter your farms across the area where you live as a form of insurance in order to get different agricultural climates.

As insurance markets improve and as farms increase in size as people move off the land and into cities, the demand for mechanization is going to take over this risk and incentive effects.

There are complementarities between designing different markets. If you design good insurance markets, then your land market might work better. If you design good land markets, then insurance markets might also work better.

There is a lot of evidence that poorer nations have lower yield than richer nations, leading to an *agricultural productivity gap*. One plausible conjecture would be that developed nations have better land, but there are studies that look at land on a square meter by square meter basis and aggregate that to show that there is no difference in potential yield between developed and developing nations. Nonetheless, the poorest 10 percent countries are only a third as productive as the richest ten percent.

There is also evidence that farmers have different levels of productivity and you might therefore want to assign more productive farmers higher quality and larger land. But, there is evidence that there is almost no correlation between farmer productivity and quality and size of land. We therefore also have a problem of *misallocation of land*. Note that we could use more evidence for this misallocation theory, and the corresponding paper to this presentation improves the quality of evidence for this theory. Further work could be done in this domain.

We might ask, “why doesn’t high quality land simply float to the most efficient farmer and its most efficient use?” There are some suggestive pieces of evidence:

- There are some studies based on land allocated through lotteries in Georgia, USA that show that markets are slow [1]

- Many developed nations have had some sort of land consolidation program run by their governments in order to achieve this goal. In these programs, a group of farmers come together and work with a geographer over a period of several years to plan their villages. Such empirical studies suggest that it takes time and a centralized program in order to consolidate land fairly and efficiently.

Figure 4: Land Fragmentation Example from Denmark

There are some fairness considerations here. In programs like the one mentioned above, farmers might have some hidden information about their plots. Typically, anecdotal evidence suggests that there seems to be consensus about which land is the best/worst. Note, however, that we have reason to believe that these evaluations are not uni-dimensional since some land might be great for growing some crops and not others and farmers may have preferences for what crops to grow. There is, however, some general quality effect. We could also use better data and evidence here.

Question: A lot of what is described above could be symptoms of market failure, but what are the mechanisms for failure? Why do we think that trade is not going to happen spontaneously?

Answer: There are several reasons why this might be the case:

- If you have increasing returns to scale, then you are going to have strong complementarities on neighboring plots. That is, for each plot, there are only a few natural purchasers, which are the individuals who own the plots next to it. Markets are very thin in this case. This implies that you have a Myerson-Satterthwaite type problem. Even in theory, we cannot come up with a solution that leads to an efficient outcome.

  This above point assumes that people do not want to move from their plots. There are a lot of reasons why they might not.

- You are going to be subject to exposure risks if you do simple, one-on-one trades. That is, if you have two scattered plots and you want to sell them both and buy one bigger plot, then you might end up selling the two plots and not have a source of income. Then, the seller for this larger plot now knows that you are a motivated buyer, and she is incentivized to hold up and extract all the surplus from the sale. If you have a chain of buyers and sellers, then each additional seller and buyer also has the same incentive. Theoretically, this would stop any trades from happening.

- Complexity is also an issue. Suppose you have 8 plots, which is not at all atypical in this setting. The complexity of chains that are involved to allow people to consolidate their land increases significantly. The chains are long and it is going to be difficult to find the most efficient trades. There is a complexity problem to finding the most efficient chains. Furthermore, if you want to find the second best mechanisms for finding efficient chains, there is the additional issue that we do not have a good theory about how people bargain over what mechanism to use.

  Note that these issues with long chains, hold up, and compatibility also show up in kidney exchange. The literature on land consolidation programs discusses land banks. That is, the government buys up the land and starts a chain of trades. This looks a lot like a good Samaritan in kidney exchanges. It would be interesting to explore this connection between the kidney exchange literature and land trade.

- There may be liquidity or credit constraints that may disallow certain trades. e.g, farmers might have land but not cash to buy a plot then sell the first plot. Selling first can lead to exposure risk.

- There are likely also issues of adverse selection. If someone wants to sell their land, then it is likely the case that the land is not as good quality as it might seem.

- It might also be the case that people have deep cultural and psychological connections to their plots of land. This is not addressed at all in this paper.

We have listed a lot of problems, and it is hard to test for how much or whether each of these is a problem. However, a market design that is robust to many of these problems and is also possible to implement in practice might subside concerns about measuring how much of a problem each of these are in practice.

We study a design that addresses several of the above problems – thickens markets, removes exposure risk, reduces complexity – and shows that farmers can, in fact, cope with the complexity of the mechanism.

3 Market Design for Land Trade

The main question here is whether the target population is able to trade efficiently using complex market mechanisms. In [2], we set up a simple land trading environment and implement a framed field experiment in rural Kenya. Specifically, we use package auctions which come with the advantage of:

There are several advantages to using such package options:

- Exposure is easy to solve with a package option. Theoretically, if the maximum number of plots that someone owns or wants to buy is less than or equal to the total number of packages that you are allowed to submit, then we should be able to get rid of exposure risk entirely.

- Farmers can bypass liquidity constraints. That is, if a farmer doesn't have money to buy something up front, but she has land that has value, then she can package it.
- Packaging also thickens markets since farmers can now bid over more plots rather than just those that are neighboring their existing plots.
- This solution should also reduce transaction costs. Rather than having farmers find chains and define rules for trade, we can use a computer program.

There are also costs associated with using such mechanisms, which can be especially high in the developing world.

- It may be difficult to describe the mechanisms and bidding process to the farmers.
- Even if the farmers understood, the winner allocation in a price-setting algorithm is opaque, and so people might not trust the system.
- People might make mistakes in entering their bids, and this would be very consequential since these are owners of small-scale farms, who often depend on these farms for a living.
- It is very hard to communicate what are the available trades: who is selling and for what price?

The key questions here are:

1. Can market design facilitate land reallocation?
2. How important are complexity concerns?
3. What does a practical/robust/optimal design look like?

As a long term goal, we would also like to come up with software solutions and complementary interventions as well as field implementations. This will be future work. Today, we discuss lab-in-field evidence from Kenya.

We use three different mechanisms of [4]:

1. *CDA broker*: farmers are able to trade single plots of land in a continuous double auction, with a broker who facilitated communication
2. *CDA swap*: similar to CDA broker, but farmers can also specify swaps
3. *CDA package*: similar to CDA swap, but farmers can also make package offers, with a maximum of two buys and two sells, where the buys are conditional on the sells, and vice versa

So, the question here is whether or not people understand these auctions well enough to use them. This would allow us to understand what the complexity constraints are for what can be implemented in practice in these settings. We want to know: can we make use of market design in the land trade problem and can we get people to participate in these auctions?

Question: Is there a strategy-proof mechanism that you can use to form chains and clear trades? Would farmers have to strategize about what prices to report or just what trades to propose?

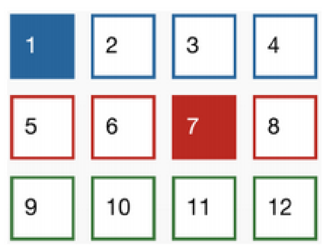
Answer: We do not have any theorems nor do we think it is plausible to get them. We think it's the same problem as the spectrum reallocation auction. The above mechanisms are not strategy-proof.

3.1 Experimental Design

This took place in rural Kenya, Kiambu county. In total, 288 farmers participated, and there were 48 experimental sessions. The sample was about 60% women since these experiments were run during the day. The average age was 43, with 10 years of education. Participants had to be land-owning farmers between ages 18-55. The women in this area often own less land and are often not the main land-owners in the family. (Average land size for this sample was 0.4 hectors of land.) Ideally, the sample would have contained more men as most households have men as the main land-owners and decision makers.

Each session consisted of 8 "land auctions" with artificial map and game currency. with 6 participating farmers. Each farmer was assigned a bid assistant who read the instruction to them and helped them enter their bids. Bid assistants were instructed not to suggest bids; they were simply there to answer any questions about the rules and instructions and enter bids into the system. All bids are XOR.

We want to study defragmentation and sorting. For each session, the farmers traded 12 plots of land located on a simplified map.



Each farmer initially had two plots. Each plot was either low, medium, or high quality (denoted by green, red, and blue squares above). We assume that the plots are the same size. Each farmer is also of low, medium, or high productivity (denoted by green, red, and blue filled in colors above).

Each session had two farmers of each type. There are complementarities in the production function. The gain for a high productivity farmer for moving to a higher productivity is higher than that for a lower productivity farmer. This accounts for the sorting. We also impose that farmers cannot farm more than two plots (e.g., they simply do not have enough time to do so). This prevents us from having one farmer own all the land.

The maps and production function remained constant across all auctions. All farmers know their own production function but not those of others'. They know which plots were owned by which farmers. In the real world, we think that people have a sense of their own as well as others' production functions.

To see whether the initial allocation of plots would affect the ease of achieving defragmentation and efficient sorting, we create eight different allocations which vary in complexity. In all cases, the farmer type is fixed and the farmer wants to have adjacent plots.

Map 1

Optimal Owner	Endowment			
(1,2) – BLUE	1	2	1	2
(3,4) – RED	3	4	3	4
(5,6) – GREEN	5	6	5	6

Map 2

Optimal Owner	Endowment			
(1,2) – BLUE	1	3	2	5
(3,4) – RED	4	6	1	3
(5,6) – GREEN	2	5	4	6

Map 3

Optimal Owner	Endowment			
(1,2) – BLUE	1	2	2	1
(3,4) – RED	3	4	4	3
(5,6) – GREEN	5	6	6	5

Map 4

Optimal Owner	Endowment			
(1,2) – BLUE	1	3	2	4
(3,4) – RED	3	5	4	6
(5,6) – GREEN	5	1	6	2

Map 5

Optimal Owner	Endowment			
(1,2) – BLUE	3	5	4	6
(3,4) – RED	1	5	2	6
(5,6) – GREEN	1	3	2	4

Map 6

Optimal Owner	Endowment			
(1,2) – BLUE	5	6	5	6
(3,4) – RED	1	2	1	2
(5,6) – GREEN	3	4	3	4

Map 7

Optimal Owner	Endowment			
(1,2) – BLUE	5	6	6	5
(3,4) – RED	1	2	2	1
(5,6) – GREEN	3	4	4	3

Map 8

Optimal Owner	Endowment			
(1,2) – BLUE	1	2	3	4
(3,4) – RED	3	4	5	6
(5,6) – GREEN	5	6	1	2

Figure 5: Examples of initial allocations of plots

Pre-experiment assessment on the complexity of these plots and the actual difficulty farmers had with it were not perfectly correlated. It remains an open question how to accurately measure complexity of initial allocations from the optimal allocation.

Note, also, we assume that the plots are the same size. This is, of course, simplistic. In the real world, a village might have hundreds of farmers and around 5 plots per farmer. The actual trades that would need to happen are much more complex.

Another open question is mapping villages to get a better sense of plot size and quality. There is very little data on what whole villages look like and what the spread of land looks like. Getting a better sense of this would be helpful for understanding what plots are easy/hard to defragment as well as how complex these trades may need to be in practice.

In the package option, the best thing to do is to bid both of your plots then put in bids for all adjacent plots. Setting prices is not easy, of course, but this would be the optimal strategy. In practice, farmers did not do this. In fact, in many cases, the farmers came up with verbal agreements after bargaining and put their bids together. Coincidentally, people in this part of Kenya are familiar with many auctions and the participants seemed to enjoy these. It remains an important caveat that the results here do not necessarily translate to other parts of the country or other parts of the world.

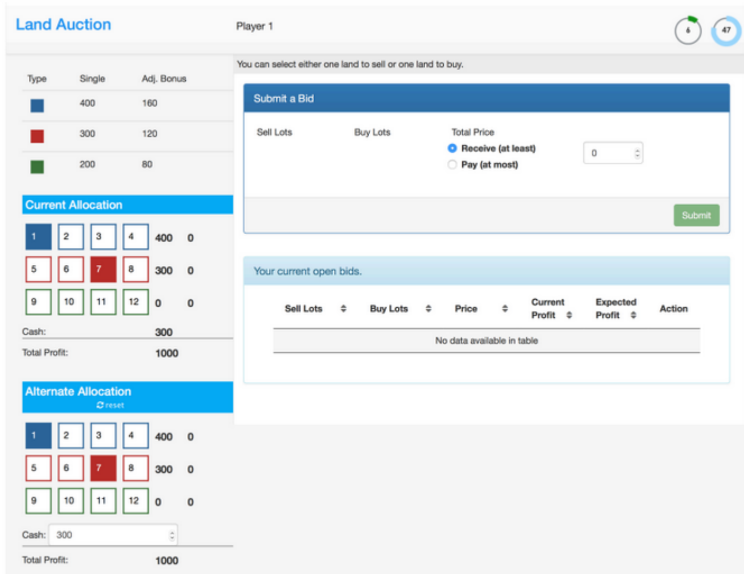


Figure 6: Sample Bidding Interface Shown to Participants

3.2 Results and Implications

We measure outcomes as a fraction of potential gain achieved over actual gain achieved. (So this value is at most 1.)

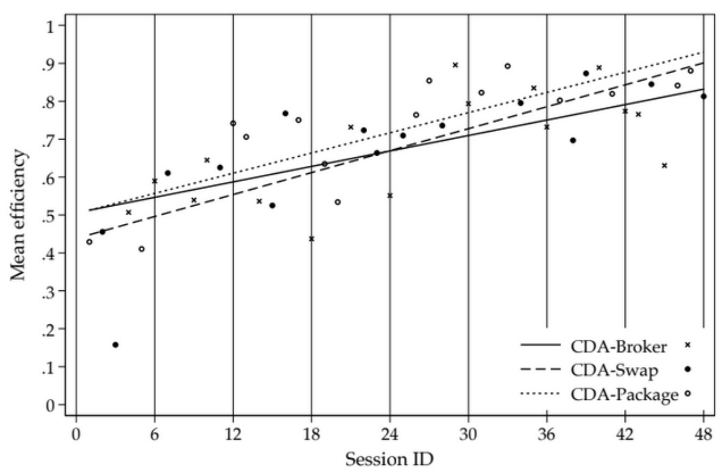


Figure 7: Time Trend in Efficiency over 48 Sessions

There are several interesting results from these experiments. The first is that efficiency is high. Farmers bid about 70 percent of the available efficiency gains across all treatments and there were few instances of losses. CDA swap did slightly better than CDA broker. CDA package did best overall, with an additional 8 percent. This demonstrates that the target sample is able to understand the market and trade well.

There is an improvement over the 48 sessions. Actual players play only once. Therefore, improvements either had to be because the assistants were helping, which they were asked not to, or because the bidding assistants were getting better at explaining the games. The assistants mentioned that they didn't know how to explain the package auction in the first few rounds but had an easier time with it over time.

The gains can be divided into defragmentation and sorting, measured by looking at the fraction of potential consolidation gains realized and fraction of potential sorting gains realized, respectively. Most of the potential gain comes from defragmentation and all three auctions perform about the same here. CDA package achieves higher efficiency, extracting 8% more surplus than CDA broker, and most of this is from sorting gain. This suggests that the farmers are able to make use of complex market design.

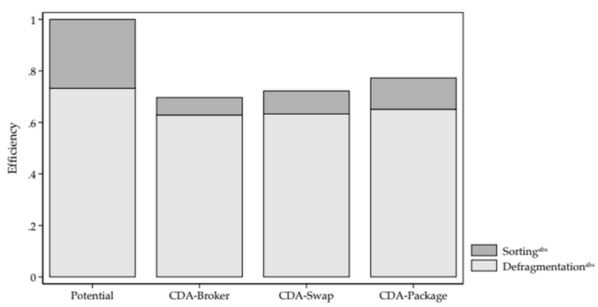


Figure 8: Realized Efficiency for Defragmentation and Sorting

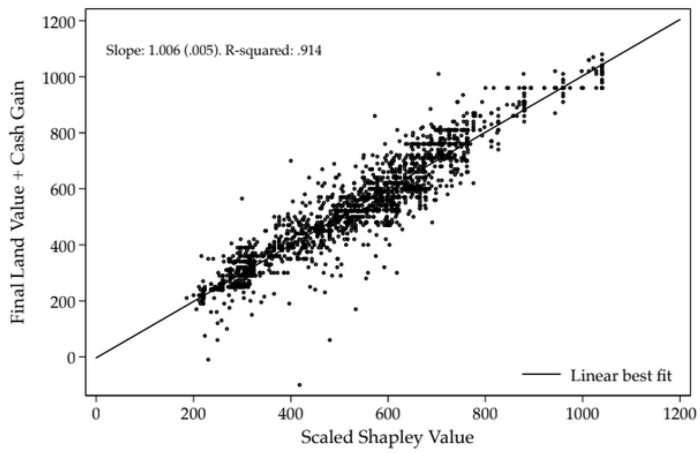
We also believe that people relied less on verbal communication for CDA package than the other two. This is measured using the number of trades that are zero surplus. (The bidding price equals the ask.) This happens if there was verbal agreement beforehand and the farmers then entered their bids at the same time. For CDA broker, this was about 40 % of the bids, although it went down over time. For CDA package, it was only about 18 %.

Farmer earnings are strongly correlated with their Shapley values. One concern about these trades is that it might increase inequality between the farmers. Exposure may lead to an asymmetric division of surplus, even if it does not create inefficiency. Farmers are also able to mitigate exposure risk. Note that this is an easy problem to solve with the package option. To understand this, we require a prediction for how surplus would be divided if bargaining was efficient and egalitarian. We plot the Shapley value, which we use as a benchmark, against ex-post division of surplus and find that there is very strong correlation. Farmers do not deviate too much from their Shapley value.

About 4% of bidders are below their Shapley value and about 1/8 % of players lost money overall. This is a concern for us in this setting, for reasons described above. We do not want any farmers to walk away with less than what they walked in. The easiest way to lose money is through exposure. But, to lose money in the package option, you had to have made a mistake in entering your bids.

In summary, about 54% of farmers reached their optimal allocation. Participants realize over 80% of the potential gains are from defragmentation and about 30% from reducing misallocation.

These results suggest that formal market institutions can play in important role in improving land allocation, and that complex design such as package exchanges can be used



Scaled Shapley value = Shapley value × $\frac{\text{Final output}}{\text{Potential output}}$.

Figure 9: Gain vs. Shapley Value for Players

effectively in a development context.

Going forward, we want to start running experiments on real farmers and real trades. It is hard to do this in the real world since governments do not usually allow it. There are various legal and cultural constraints: e.g., traditional land rules, laws that require not buying/selling land, etc. Land can be extremely contentious and political.

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