Wheat or Strawberries? Intermediated Trade with Limited Contracting.

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Abstract

Why do developing countries fail to specialize in products in which they appear to have a comparative advantage? We propose a model of trade with intermediation that explains how hold-up resulting from poor contracting environments can produce such an outcome.

A temporary production subsidy, or a marketing board that commits to purchase from the producer ensure production of the intermediated good. We use the model to evaluate welfare implications of policies, and explain partial pass through of the consumer prices to the producer.

There is a large literature that documents that labour productivity in developing countries is orders of magnitude smaller than that in developed ones, and that this is more so in agriculture than in manufacturing. For example, Caselli, 2005 shows that aggregate productivity for countries at the 90^{th} percentile of income relative to the 10^{th} percentile is 22, while this ratio for agriculture is 45. Despite this, most developing countries tend to be predominantly agricultural economies.

These differences in agricultural productivity could arise from differences in efficiencies conditional on the set of products made and/or composition effects. In other words, farmers in developing countries could be allocating the bulk of their labor to the production of capital intensive staples, like wheat, rather than high value fruits and vegetables. These staples can be produced efficiently on large plots of land using machines, fertilizer and pesticides. Fruits and vegetables, especially tropical ones, could be efficiently produced in the developing countries and exported. Lagakos and Waugh, 2013 show that for maize, rice, and wheat the ratio of output per worker in the top and bottom 10% of countries is 146, 90, and 83 respectively. The analogous ratio for agricultural sector as a whole is just 45. Yet, farmers in developing countries persist in producing staples like wheat, corn or maize, rather than exotic produce, what we call strawberries, that are highly valued in urban areas or export markets.

We explain why this takes place using a model of agricultural trade with intermediation where contracts on price cannot be enforced, as often is the case in the developing countries. In our set up, farmers in the developing world have the technology to produce both staples and exotic produce. Farmers choose to produce staples, e.g., wheat, because they can survive on their wheat if the need arises, while they cannot survive on strawberries. Not only are strawberries nutritionally inadequate, but they are perishable, and have to be sold quickly. This gives intermediaries bargaining power when markets are thin, and makes farmers reluctant to grow strawberries. This in turn makes intermediaries reluctant to enter, resulting in the expected thin markets materializing.

The environment in a developing country is very different from that in a developed one. A number of factors limit a farmer's ability to transport his strawberries to an urban or export location himself: roads are poor, trucks are expensive, and credit markets are poorly developed. Hence a farmer must rely on intermediaries (traders) to deliver his produce. At the same time, traders are scarce, irregular in their arrivals, and unreliable, as contracts are poorly enforced.

Central to our story is the inability of farmers and traders to contract ex ante on price. The absence of enforceable contracts precludes negotiating the terms of trade prior to production and sets the stage for the classic hold up problem. If contracts were enforceable, traders and farmers could search for matches in the beginning of the period and then make production decisions after bargaining over the surplus from the match. The price of the good would be determined by the farmers outside option: producing the staple good.

Here we consider an environment where such contracts cannot be made as the trader has an incentive to defect from such arrangements ex post. This environment produces the central coordination failure we study: farmers would choose to produce strawberries if they could count on a buyer and buyers would put up the sunk costs of entry if there were farmers making strawberries. However, depending on what agents believe, we may have the opposite happen in equilibrium.[1]

In other words, if the product is produced by many agents and there are many intermediaries, the market functions well and the developing country can specialize according to comparative advantage. Though improvements in the contracting environment can alleviate the holdup problem, the required judicial and political reforms to do this are hard and time consuming to implement. We therefore take as given the problematic contracting environment in the less developed countries.

In the following section we develop a simple model that captures essential features of the environment in which agricultural producers (and producers more generally) operate in the less developed countries. Our model is designed to evaluate the effects of the various policy options that

[1]Other reasons why agricultural exports from developing countries are problematic have to do with phyto-sanitary requirements. For example, Indian mangoes can not be exported to the US without being irradiated, which was infeasible prior to the nuclear deal struck during the Bush Administration. In the same vein, Australia and New Zealand, with their strict phytosanitary requirements, are difficult export markets to crack, especially for developing countries. These laws can also be abused. See Engel, 2001 for some illustrations.

might be open to a government or an NGO.

In our model farmers can produce two goods that differ along three dimensions: the farmer's ability to consume them, the farmer's efficiency in producing them, and the kind of market in which they are traded. The first good is what we have been calling wheat, is a staple that has a local market. Farmer can subsist on wheat alone though they are relatively inefficient at making it, and with perfect markets, would not choose to do so. The second good, that we have been calling strawberries, is a non staple and farmers cannot subsist on strawberries. In addition, strawberries are perishable so the farmer cannot just store them and wait for a trader to show up.

In the developing world, the perishability of goods is accentuated by poor storage conditions that farmers face, as well as the lack of access to credit. Even goods that are potentially storable can deteriorate rapidly in the presence of vermin and the absence of refrigeration.[2] Moreover, as agents in developing countries live from hand to mouth, they do not have the luxury of waiting for a better offer, even if one is likely. Interest rates from informal sources are very high, rates of 20% a month are not uncommon, and formal credit is very hard to obtain. All of this heightens the "perishability" of the non staple good.

Traders, unlike farmers, have access to a Walrasian market and can sell the good at the given world price. Traders incur a sunk cost of entry, which captures their transportation and opportunity costs. Farmers and traders cannot contract on price ex-ante. They meet randomly and there is free entry of intermediaries. When a farmer and a trader meet, the trader offers the farmer a price and the farmer accepts or rejects it. When the trader makes the offer he does not know the number of rival traders who have visited a given farmer or the prices they have offered. However, a trader does know how likely each outcome is and makes his decisions based on the probability distribution over competitors' price offers. The trader who offers the highest price to the farmer gets the good. Of course, there may be no traders at a farmer's doorstep, in which case the farmer exercises his

[2]Estimates suggest that as much as 22% of wheat production is lost to vermin in India. For fresh fruit and vegetables, the loss may be over 50%. See for example, "Farmers Plagued by Post Harvest Food Losses", August 31, 2011, *The Gleaner*, Kingston, Jamaica.

outside option, which may be zero.

We solve the model and characterize all the possible equilibria as a function of the four primitive parameters: productivity in the export good, price of the export good in the world and the local markets, and the sunk cost of intermediation. Of particular interest is the region in parameter space with multiple equilibria. In the "good" equilibrium farmers specialize in strawberries, which they produce more efficiently than the staple, and there is intermediation. In the "bad" equilibrium, there is no intermediation and the staple is produced. When inter-temporal contracts between farmers and sellers are not enforced market failure is endemic as long as there is no local market for strawberries.

Our work suggests that there are simple policies to ensure intermediation and specialization according to comparative advantage even if the government is not able to resolve the core issue: the underlying lack of enforceable contracts. When primitive parameters are such that there are multiple equilibria: a temporary production subsidy, or a marketing board that ensures a sufficiently high minimum price to the farmer, can remove the bad equilibrium without intermediation.[3] In contrast, reduction of entry cost of intermediaries or investment in agricultural productivity do not ensure that the investment will take off.

A number of policies can improve social welfare of an economy in a "good" equilibrium, when intermediation and specialization are already present. For example, our work suggests a new reason for promoting extension programs that aim to improve agricultural productivity. Not only do such programs directly raise farmers output and income, but by encouraging intermediation, they increase competition among traders so that farmers obtain a higher expected price for their produce.

Our results also have implications for the efficient operation of a marketing board. We show that when intermediaries are more efficient than the marketing board, social welfare is maximized when a marketing board that makes zero profits. When the marketing board is more efficient than the intermediaries, a marketing board that is the sole buyer that pays the producer price high enough to drive out the intermediaries yields the highest

[3]In the presence of risk aversion, as shown in the Appendix, these policies have an extra bang as there are additional production effects that amplify their effects.

level of welfare. Thus we make a case for having marketing boards who set the farmer's price as high as possible on the basis of overall welfare, not distributional concerns.

Our work also has a number of results that shed new light on some classic questions. We provide an alternative explanation as to why increases in world prices may not feed back fully into prices obtained by farmers[4], especially in the short term.

0.1 Motivating the Modelling Assumptions

In the model we make a number of assumptions that drive our results. In particular we assume that intermediaries play an essential role in delivering strawberries from the farmer to the world market. Furthermore we also assume away the possibility of enforcing contracts through repeated interactions. In this section we provide some evidence in support of these assumptions.

Fafchamps, Gabre-Madhin and Minten, 2005 find that intermediaries play an important role in facilitating agricultural trade in developing countries. They document that market liberalization in poor countries has resulted in multiple layers of intermediaries. There is a large number of small intermediaries and a few large ones. Large traders specialize in wholesaling and rarely sell retail. They rarely buy directly from producers, buying instead from many small itinerant traders who specialize in buying from producers and selling to wholesale traders or organized markets. In our model we focus on these small itinerant traders who mediate between the organized market and small producers. They are large in total number, but small in terms of their presence in any particular neighbourhood.

Fafchamps and Hill, 2005 document that farmers face a decision whether to sell at the farm gate or to travel to the nearest centralized market to sell the good. Farmers are less likely to travel to the local market and more likely to sell to the local trader when the nearest market is far or the cost of transportation is high. Similarly, Osborne, 2005 finds that in poorer and more remote areas, traders have more market power than in markets that are close to big trading centers. In our model we allow the presence of a

[4]This has been noted for coffee farmers by Fafchamps and Hill, 2008.

local market for the export good in the form of an "outside option" for the farmer in his interactions with the trader. In other words, the farmer will find it worthwhile to sell at his door only if the trader offers a price at least as good as the price he can obtain in the local market, which may be zero if such a market does not exist.

A historical example of the holdup problem that we focus on in the paper, and one solution to it, can be found in Kranton and Swamy, 2008. They argue that the Opium Agency, initiated by the East India Company (EIC) in India, had a similar problem and recognized it. As the agency was the sole procurer of opium it had monopsony power. In order to prevent the agents of the EIC from behaving opportunistically with respect to the farmers, which would have reduced the incentives to produce opium on their part, the Opium Agency expended significant resources monitoring their own agents. Kranton and Swamy, 2008 also assume there are no relational contracts possible and for reasons similar to our own.

The role that dairy cooperatives played in establishing the diary industry in India, e.g., Amul, is another anecdote that supports our model. In India prior to "Operation Flood", milk was hard to come by in urban areas. Farmers were reluctant to produce milk because of the risk of spoilage and the lack of distribution channels for their milk. Urban consumers would buy milk from small scale "milkmen" who transported their milk door-to-door on bicycles without refrigeration or quality control. Dairy cooperatives that took hold in India during "Operation Flood" shared rents with the farmers by giving them a "fair" price for their milk. They provided the refrigeration, quality control and marketing services for milk and milk products, like yogurt and cheese, needed to serve urban consumers, as well as extension-services to improve productivity. Their success produced a flood of milk and was a key part of the "white revolution" in India. India went from being a milk deficient nation in the 1970s to being the worlds largest milk producer in 2011.[5]

An important feature of our work is that we do not allow for the possibility of repeated interaction between farmers and traders. There is considerable uncertainty in developing countries: weather variability, political

[5]See Delgado, Narrod and Tiongco, 2003 for more on how the white revolution occurred in India.

uncertainty and disease, all of which make people focus on the short term so that the future is highly discounted. Such considerations call for the use of static models that exclude repeated interactions and relational contracting.

The long term relations and reputational concerns have received a lot of attention in recent years and have been shown to play an important role in facilitating contracts. Banerjee and Duflo, 2000 focus on the role played by repeated interactions in the software industry in India. Macchiavello and Morjaria, 2012 focus on the role of repeated interactions in the context of rose exports from Kenya, while McMillan and Woodruff, 1999 look at credit relations between firms in Vietnam. Antras and Foley, 2011 show that prepayment for orders is more common when relational capital is low, i.e., at the start of a relationship. Greif, 2005 uses historical examples to study how contractual problems were resolved among Magrabi traders. All these are established markets. Here we focus on why certain markets do not come into being when there is no repeated interaction, rather than on the operation of established markets.

0.2 Relation to Existing Work

Although this paper is cast as a model of agricultural trade, it relates to a number of other areas in development.

The big push types of stories as in Nurkse, 1966 and Rosenstein-Rodan, 1943 and more recently Murphy, Shleifer and Vishny, 1989 emphasize that a firm's decision whether to industrialize or not depends on its expectation of what other firms will do. In particular, they emphasize the role of demand externalities. While industrializing for any one firm is unprofitable, if all firms industrialized simultaneously increased profits of the firms would generate greater aggregate demand making industrialization profitable for each individual firm.

In contrast to the "big push" idea is the unbalanced growth literature. This suggests that producing some goods is more growth enhancing than others and that coordination failures may result in a sub optimal outcomes. Hirschman, 1988, suggests that sectors with greater linkages (both backward and forward) are likely to be more growth enhancing, and that there may be a role for government to intervene. This literature tends to focus on complementarities that result in coordination failure that may create a role for government intervention. Instead, we focus on the contracting imperfections that result in the coordination failures that make farmers choose to produce low priced staples.

Hausmann and Rodrik, 2003 and Hausmann, Hwang and Rodrik, 2007 portray development as a process of self discovery. In their framework entrepreneurs do not know which products a country can produce efficiently until someone tries it. Trials involve uncertainty and are costly. Moreover, if products can be easily replicated a successful innovator will soon face tight competition. This way the cost of innovation is private, while the benefit is public. As a result, too little discovery occurs. Our model does not rely on such informational frictions to explain the lack of investment in non traditional products. With contractual frictions farmers know about their options but choose not to avail of them because non traditional product markets are thin and holdup is likely.

Our work is also related to Antras and Costinot, 1993 which introduces intermediation into a two-good two-country Ricardian framework. Their focus is on the implications of globalization in the presence of intermediation. They find that integration of the commodity markets produces gains for both countries, while integration of matching markets (markets where intermediaries and producers/farmers meet) leads to welfare losses if in the country where intermediaries are less efficient and have less bargaining power. In their model producers and intermediaries form matches and bargain over the surplus with exogenously given bargaining power and an endogenous outside option. In contrast, in our model, the terms of exchange between farmers and traders are endogenously determined: traders who show up at the farm gate participate in a first price auction. If the market is thick, there is more competition in this auction. Our focus is on the implications of search frictions and lack of enforceable contracts on specialization patterns with a view to policy. For example, our results suggest that extension programs that improve productivity of the intermediated good will result in farmers gaining both because they are more productive, and because greater productivity improves intermediation so that they also get more for what they make when their productivity rises.

Our paper is also related to a small literature focusing on the price transmission mechanism in agricultural trade from retail market to the producer price and more broadly on the gap between producer and consumer prices. Fafchamps and Hill, 2008 analyze transmission of the export coffee price to the Uganda farmer who sells at the farm gate. Their analysis is based on original data collected by the authors on all coffee exporters as well as on a random sample of coffee traders and producers in Uganda. They find that when the international price rises, domestic prices follow suit, except for the price paid to producers, which rises by far less than the international price. They argue that the cause of this incomplete pass through is the lack of information about world price movements on the part of the farmer. World price increases attract more traders into the market which dissipates the rents, and due to farmers' ignorance of the world price, there is little or no benefit to them. There is no direct test of the information friction hypotheses in their model. It is important to understand why farmer prices are low: if they are low because of trade frictions, then providing information to farmers, say by posting the world price in a public place, would not help raise the price they obtain or affect the extent of pass through. This is exactly what is found in Mookherjee, et. al (2011). However, this is not to say that greater cell phone usage, if it reduced the cost to a trader of visiting a farmer, and so led to a flood of trader entry, would not raise the price offered to farmers.

We proceed as follows. Section 1 lays out the model. Section 2 constructs the equilibrium when farmers are risk neutral. Section 3 looks at the efficacy of various policy options. Three kinds of policies are considered: decreasing the cost of entry for traders, a production subsidy to farmers, and raising the outside option for the farmers closer to the world price. Section 4 concludes. Extensions to risk averse farmers and details of proofs are in the online Appendix.

1 The Model

The modelling framework builds on Burdett and Mortensen, 1998 and Galenianos and Kircher, 2008. The economy consists of a continuum of farmers of measure one and a continuum of traders whose measure is determined endogenously in equilibrium. Farmers can produce a staple or a perishable good. One unit of labour produces one unit of the staple and α units of the perishable good. Each farmer is endowed with one unit of labour. Farmers can consume the staple themselves or sell it at a fixed price which is normalized to unity.

The perishable good has to be exchanged for the staple in a Walrasian market, i.e. the world market which has a single market clearing price, to which farmers have no access without intermediaries. To exchange the perishable good farmers have to meet with a trader. The role of the trader in this model is to deliver the good from the farmer to the Walrasian market. His objective is to maximize his expected profit. There is an infinite number of potential traders who can become actual traders by paying a sunk entry cost, κ. Each trader who paid the sunk cost randomly meets a single farmer. For the farmer it is possible that more than one trader approach him. The trader at the time he makes the offer does not observe how many traders he is competing with. However, he knows the ratio of traders to farmers in the market and so can infer the probability distribution over the number of potential competitors. The good is then allocated to a trader through the first price auction mechanism: in other words, the trader who offers the highest price gets the product.

The model is static. Farmers and traders simultaneously choose their strategies. The strategies are played and the outcomes are revealed. The farmer chooses how much labour to allocate to the production of the intermediated good , $l \in [0, 1]$. $1 - l$ is allocated to the production of the subsistence good. The strategy of a potential trader consists of a binary decision to enter or not, and the price distribution to offer conditional on entry. All agents take the strategies of all other traders and farmers as given.

All farmers and traders are ex-ante identical and of measure zero so that their individual actions do not affect the equilibrium outcome. We begin by assuming that farmers and traders are risk neutral. This causes farmers to specialize in either the export or the staple good. Adding risk aversion on the side of the farmers moves the economy away from the corner solution as farmers diversify their output. We do so in the Appendix B. This makes the supply of the export and staple good a continuous function of the model's parameters.

1.1 The Meeting Process

We assume that farmers and traders meet randomly according to a Poisson Process. This process arises naturally when traders arbitrarily meet one out of N farmers producing for export, and is convenient in modelling coordination frictions that result when there are many small market participants.

Let P_k be the probability that a trader who randomly arrives at the gate of one of the farmers in meets k rivals. Let $\lambda = \frac{1}{N}$ is the probability that a given trader visits this farmer. Then P_k is given by:

$$P_k = \binom{T-1}{k} \lambda^k (1-\lambda)^{T-1-k}.$$

Denote the ratio of traders to farmers by $\theta = \frac{T}{N}$. Rewriting P_k in terms of θ and λ yields

$$\begin{aligned} P_k &= \binom{T-1}{k} (\frac{1}{N})^k (1-\frac{1}{N})^{T-1-k} \\ &= \frac{(T-1)!}{(T-1-k)!k!} (\frac{\theta}{T})^k (1-\frac{\theta}{T})^{T-1-k} \\ &= \frac{(T-1)!}{(T-1-k)!T^k} \frac{(\theta)^k}{k!} (1-\frac{\theta}{T})^T (1-\frac{\theta}{T})^{-(1+k)}. \end{aligned}$$

Now let T and N go to infinity keeping θ constant. Then $\lambda = \frac{1}{N}$ goes to zero while θ is a finite number.

Thus,

$$\begin{aligned} \lim_{T,N\to\infty} P_k &= \lim_{T,N\to\infty} \frac{\theta^k}{k!} \left[\frac{(T-1)!}{(T-1-k)!T^k} \right] \left[(1-\frac{\theta}{T})^T \right] \left[(1-\frac{\theta}{T}) \right]^{-(1+k)} \\ &= \frac{\theta^k}{k!} e^{-\theta}. \end{aligned}$$

This follows from

$$\lim_{T\to\infty} \frac{(T-1)!}{(T-1-k)!T^k} = \lim_{T\to\infty} \frac{(T-1)(T-2).....(T-k)}{T^k} = \lim_{T\to\infty} (1-\frac{1}{T})...(1-\frac{k}{T}) = 1$$

and

$$\lim_{T\to\infty}\left[(1-\frac{\theta}{T})\right]^{-(1+k)} = 1.$$

Also, by definition $e = \lim_{T\to\infty}\left[(1+\frac{1}{T})^T\right]$, so that

$$\lim_{T\to\infty}\left[(1-\frac{\theta}{T})^T\right] = e^{-\theta}.$$

Thus, for a sufficiently large number of market participants the probability that a trader meets k rivals, or P_k, is given by $\frac{\theta^k}{k!}e^{-\theta}$.

1.2 The Trader's problem

The trader's problem consists of two parts. For a given level of market intermediation, that is, for the given number of traders and producers, a potential trader needs to decide whether to enter the intermediation market or not. Upon entry he has to decide what price to offer to the farmer that he visits. As usual, we need to solve this backwards. First, consider the problem of optimally choosing the price to post, given the number of traders in the market.

As all traders are ex-ante identical, we limit ourselves to considering only the symmetric equilibria. The trader knows that for an arbitrary p, the probability that it is the highest price posted in a meeting with k rivals is given by $[F(p)]^k$. Thus, if he meets k rivals and offers p, he will be the highest bidder with probability $[F(p)]^k$. As discussed earlier, for a large T and N, the number of rivals in a meeting is given by the Poisson process. Hence, the unconditional probability that a trader offering price p is the highest bidder involves summing over the number of rivals the trader could potentially meet:

$$\begin{aligned}
\sum_{k=0}^{\infty} P_k[F(p)]^k &= \sum_{k=0}^{\infty} e^{-\theta}\frac{\theta^k}{k!}[F(p)]^k \\
&= \sum_{k=0}^{\infty} e^{-\theta}\frac{[\theta F(p)]^k}{k!}. \\
&= e^{-\theta}e^{\theta F(p)} \\
&= e^{-\theta(1-F(p))}
\end{aligned}$$

If a trader offering p wins, he makes $\left(P^{w}-p\right)\alpha l^{*}$ where αl^{*} is the quantity of the export good the farmer has made. The probability of actually being the highest bidder is $e^{-\theta(1-F(p))}$. Thus, the expected profits of a trader offering price p, conditional on the farmer making the export good are given by:

$$\pi(p)=\left(P^{w}-p\right)\alpha l^{*}e^{-\theta(1-F(p))}.$$

In equilibrium any price in the support of the trader's mixed strategy, $F(p)$, must yield the same profits. Thus, $\pi(p)=\overline{\pi}$, for every p in the support.

Let R be the price which a farmer can obtain if he does not meet a trader. This may be the price offered, for example, by the local canning factory. It may be zero if the export good is wasted when not sold to a trader, or can be interpreted as the price net of costs obtained by a farmer travelling to the local market. The value of R puts a lower bound on the price that the farmer will accept for his output.

Proposition 1. *In the symmetric mixed strategy equilibrium, traders mix over the interval* (R,p^{max}) *according to* $F(p)$ *where*

$$F(p)=\begin{cases} 0 \; for p<R \\ \frac{1}{\theta}\ln(\frac{P^{w}-R}{P^{w}-p}) \; for R\leq p\leq p^{max}, \end{cases} \tag{1}$$

and expected equilibrium profits equal $(P^{w}-R)\alpha l^{*}e^{-\theta}$.

Proof. First, we show that the support starts at R, has no gaps and the distribution function is continuous, i.e., the density function has no mass points. Since no farmer will accept a price below R, the support of $F(\cdot)$ cannot include any such points. Suppose the support of $F(\cdot)$ starts at $\underline{p}>R$. Then a trader who bids a price in the interval $\left[R,\underline{p}\right)$ will only win if there are no other traders, i.e., with probability $P_{0}=e^{-\theta}$. His expected profit is:

$$\pi(p)=(P^{w}-p)\alpha l^{*}e^{-\theta},$$

which are decreasing in p. Thus, the trader would be better off charging R, or any price in $\left[R,\underline{p}\right)$ than offering $\underline{p}$ which contradicts the assumption that $\underline{p}$ is in the support of the mixed strategy equilibrium.

Next, we establish that there are no gaps or atoms in the support of the distribution.

Let us first rule out gaps in the support of the distribution. Suppose there is a gap in the support of $F(\cdot)$: no one bids in the interval (p', p''). If there is no mass point at p'', then a trader who posts a price $p^* \in (p', p'')$ will be better off than bidding $p^{''}$, as the probability of winning does not decrease, but the profitmargin rises. Hence, there are no gaps in the support unless there is a mass point at p''. Such a mass point would cause a jump down in profits at prices just below p'', and validate the gap in support of the posited price distribution. Can we rule out such atoms at p''? Yes, we can. If there is an atom at p'', then bidding $p'' + \varepsilon$ causes a discrete jump in trader's profits as he increases the offer price only marginally, but this increases his probability of winning discretely.

The same argument rules out atoms at any $\widehat{p}$ in the interior of the support of the distribution or at R: bidding $p = \widehat{p} + \varepsilon$ causes a discrete jump in trader's profits as he increases the offer price only marginally, but this increases his probability of winning discretely. In equilibrium all prices in the support must yield the same profits, hence such mass points cannot occur. They cannot even occur at the upper end of the support. As will be confirmed later, the upper end of the distribution support is given by $p^{\max} < P^w$. If there were a mass point at $p^{\max}$, raising p slightly above $p^{\max}$ must raise profits which rules out a mass point at $p^{\max}$.

Next we can use the property of the equality of payoffs at every point of the support to obtain the explicit expression for the cumulative distribution of bids, $F(p)$. Equating the expected profits at an arbitrary price p and expected profits at the lower end of the support R , i.e., setting $\pi(p) = \pi(R)$, we can solve for the bidding function of the trader as a function of world price (P^w), market thickness (θ), and the farmer's outside option (R):

$$\begin{aligned}
(P^w - p)e^{-\theta(1-F(p))} &= (P^w - R)e^{-\theta} \\
e^{\ \theta F(p)} &= \frac{(P^w - R)}{(P^w - p)} \\
F(p) &= \frac{1}{\theta}\ln\left(\frac{P^w - R}{P^w - p}\right).
\end{aligned}$$

At the upper end of the support the cumulative density function equals unity. Hence solving

$$F(p^{\max}) = 1 = \frac{1}{\theta}\ln(\frac{P^w - R}{P^w - p^{\max}})$$

for $p^{\max}$ yields the expression for the upper end of the support:

$$p^{\max} \quad = \quad P^w(1 - e^{-\theta}) + e^{-\theta}R.$$

□

The upper bound of the support is a convex combination of the world price and the farmer's reservation price. To see this note that $e^{\theta} = 1 + \theta + \frac{\theta^2}{2!} + \frac{\theta^3}{3!}... > 1$ for any $\theta > 0$ and thus, $0 < e^{-\theta} < 1$. As the level of intermediation increases p_{max} approaches P^w from below, but as $e^{-\theta} < 1$ for any value of θ p_{max} remains below P^w. Farmer's reservation price, R binds the value of p_{max} from below. Hence, $p^{\max}$ is increasing in the prevalent level of intermediation, θ, the farmers' outside option, R, and the world price of the intermediated good, P^w.

When αl^* is the equilibrium output of the intermediated good, the expected profits of the trader are

$$\pi(p) = (P^w - R)\alpha l^* e^{-\theta}.$$

They are increasing in P^w, and decreasing in R and θ.

Now that we can evaluate traders' expected profits prior to entry, we can consider trader's entry decision.

Proposition 2. *The free entry level of intermediation is*

$$\theta = \begin{cases} \ln(\frac{(P^w - R)\alpha l^*}{\kappa}) & \textit{if} \;\; l^* \geq l_{\min} \\ 0 \; \textit{if} \; l^* < l_{\min} \end{cases} \tag{2}$$

Proof. There is an infinite number of potential traders who can enter if their expected profits from entry exceed the sunk cost of entry. Entry of traders will continue until the benefits from entry exactly equal the costs:

$$\pi(p) = \kappa.$$

Since profits are the same at every point in the support, without loss of generality we can solve for the level of intermediation by equating profits at the lower end of the support, R, to the cost of entry ,κ:

$$(P^w - R)\alpha l^* e^{-\theta} = \kappa.$$

Solving for θ gives

$$\theta = \ln\left(\frac{(P^w - R)\alpha l^*}{\kappa}\right).$$

Thus, the equilibrium level of intermediation is increasing in the world price and the output of the export good. It is decreasing in the sunk cost and the farmer's reservation price. Note that $\theta > 0$ if and only if

$$\ln\left(\frac{(P^w - R)\alpha l^*}{\kappa}\right) > 0,$$

or

$$l^* > l_{\text{min}} = \frac{\kappa}{\alpha(P^w - R)}.$$

□

Proposition 2 says that positive levels of intermediation prevail when the output of the export good αl^* is higher than the minimum level denoted by $\alpha l_{\text{min}} = \frac{\kappa}{(P^w - R)}$, which ensures that the profits made from trading the export good exceed the sunk cost of doing so. Equilibrium level of intermediation is higher when the world price is higher, the farmers' reservation price is lower, or the sunk cost of entry into intermediation is lower.

1.3 The Farmer's Problem

Having characterized the traders' problem, we now describe the problem of a risk neutral farmer and consider the implications of the model for policy in this setting.

Let $G_k(p) = [F(p)]^k$ be the cumulative density function of the highest price offered when the farmer meets k traders. Each farmer has a linear utility function defined over the units of the staple good. A farmer who allocates l units of labor to the intermediated good and $1 - l$ units to the staple, and receives price p from a trader for the intermediated good makes

$$\pi(l,p) = (\alpha p - 1)\, l + 1.$$

Since the farmer is risk neutral he maximizes the expected value of his profits, and since he only consumes the numeraire good, his indirect utility is the same as his income.

Let $E(p)$ be the price farmers expect to fetch for the export good. Note that if $\alpha E(p) - 1 > 0$, the farmer will produce only the non staple.

Lemma 1. *As the number of traders and farmer goes to* ∞*, the probability that a farmer meets* k *traders, or* Q_k*, is given by* $\frac{\theta^k}{k!}e^{-\theta}$.

Proof. With a finite number of traders, denoted by T, in the market the probability of the farmer having k traders arrive at his door is given by

$$Q_k = \binom{T}{k}\lambda^k(1-\lambda)^{T-k}.$$

Denote the ratio of traders to farmers by $\theta = \frac{T}{N}$ and the probability that a given trader visits this farmer $\lambda = \frac{1}{N}$. Rewriting Q_k in terms of θ and λ yields

$$\begin{aligned} Q_k &= \binom{T}{k}\left(\frac{1}{N}\right)^k\left(1-\frac{1}{N}\right)^{T-k} \\ &= \frac{(T)!}{(T-k)!k!}\left(\frac{\theta}{T}\right)^k\left(1-\frac{\theta}{T}\right)^{T-k} \\ &= \frac{(T)!}{(T-k)!T^k}\frac{\theta}{k!}^k\left(1-\frac{\theta}{T}\right)^T\left(1-\frac{\theta}{T}\right)^{-(k)}. \end{aligned}$$

Thus

$$\begin{aligned} \lim_{T,N\to\infty} Q_k &= \lim_{T,N\to\infty}\frac{\theta^k}{k!}\left[\frac{T!}{(T-k)!T^k}\right]\left[\left(1-\frac{\theta}{T}\right)^T\right]\left[1-\frac{\theta}{T}\right]^{-(k)} \\ &= \frac{\theta^k}{k!}e^{-\theta}. \end{aligned}$$

□

Farmers take the level of intermediation θ, the pricing strategy of the traders $F(\cdot)$, and the meeting process $\{Q_k\}_{k=0}^{\infty}$ as given.

Lemma 2. *Given the level of intermediation, θ, the expected price is given by*

$$\begin{aligned} E(p) &= \sum_{k=0}^{\infty} Q_k \int_{R}^{p_{\max}} p dG_k(p) \\ &= P^w - e^{-\theta}(P^w - R)(1+\theta) \\ &= P^w \left(1 - e^{-\theta}(1+\theta)\right) + Re^{-\theta}(1+\theta). \end{aligned} \tag{3}$$

As $0 < e^{-\theta}(1+\theta) < 1$, the expected price is a convex combination of the world price and R.[6]

Proof. As this proof involves lengthy algebra, it is placed in the Appendix. □

The expected producer price increases with the world price, P^w, the producer reservation price, R, and the level of intermediation, θ.

A risk neutral farmer allocates labour between production of the export good and the staple depending on the price of the intermediated good. When $E(p) > \frac{1}{\alpha}$ then he specializes in the intermediated good. When $E(p) < \frac{1}{\alpha}$ he produces only the staple good. When $E(p) = \frac{1}{\alpha}$, the farmer is indifferent in between producing the intermediated or the staple good. Hence, the farmers' best response function is given by:

$$l(E(p)) = \begin{cases} 1 \text{ if } \alpha E(p) > 1 \\ [0,1] \text{ if } \alpha E(p) = 1 \\ 0 \text{ if } \alpha E(p) < 1. \end{cases}$$

An increase in θ raises the expected price as it reduces the weight on R. As θ rises and $E(p)$ exceeds $\frac{1}{\alpha}$, farmers specialize in the production of the export good and $l(.) = 1$. Let $l(E(p|\theta)) \equiv l(\theta)$. Then, we can write the farmers' best response function above as:

[6] $e^{\theta} > 1 + \theta$ so $\frac{1}{1+\theta} > e^{-\theta}$ or $1 > e^{-\theta}(1+\theta)$.

$$l(\theta) = \begin{cases} 1 \ for \ \theta > \theta_{\min} \\ [0,1] \ \text{ if } \theta = \theta_{\min} \\ 0 \ for \ \theta < \theta_{\min} \end{cases} \quad (4)$$

where $\theta_{\min}$ is the solution to $E(p|\theta) = \frac{1}{\alpha}$. It is easy to see that $\theta_{\min}$ does not depend on κ and decreases as α rises.

1.4 Equilibrium

In the Nash equilibrium, each farmer chooses what to produce so as to maximize his profits, each active trader is choosing what price to offer, all potential traders are indifferent between becoming active or not, and the decisions of these agents are mutually consistent.

An equilibrium consists of three objects: $\theta, F(p), l(\theta)$. θ is the level of intermediation, the equilibrium ratio of traders to farmers. $F(p)$, is the distribution of prices for the export good that the profit maximizing trader offers in equilibrium; and $l(\theta)$ is the output of the intermediated good by the profit maximizing farmer.

To summarize, so far, we have the following:

1. The farmer's best response function:

$$l(\theta) = \begin{cases} 1 \ for \ \theta > \theta_{\min} \\ [0,1] \ \text{ if } \theta = \theta_{\min} \\ 0 \ for \ \theta < \theta_{\min} \end{cases} \quad (5)$$

where $\theta_{\min}$ is the solution to $E(p|\theta) = \frac{1}{\alpha}$.

2. The trader's free entry condition:

$$\theta = \begin{cases} \ln\left(\frac{(P^w - R)\alpha l(.)}{\kappa}\right) > 0 \text{ if } l(.) > l_{\min} = \frac{\kappa}{\alpha(P^w - R)} \\ 0 \text{ if } l(.) < l_{\min} \end{cases} \quad (6)$$

$\theta(l)$ is zero for $l < l_{\min}$. If farmers produce less than $l_{\min}$ the expected profits from buying the export good from the farmer and reselling it to the trader fall short of covering the sunk cost of entry. For values of l greater than $l_{\min}$ $\theta(.)$ rises with l[7]. $l_{\min}$ depends on the primitive parameters κ, R,

[7]We already know that $l(.)$ is going to be either zero or unity. If no farmer makes the specialized good, then no traders will enter and $\theta = 0$. Given no traders will enter,

α, P^w, and moves together with κ and R and in the opposite direction to α and P^w.

3. Distribution of price offers:

The distribution of prices in equilibrium is:

$$F(p) = \frac{1}{\theta}\ln(\frac{P^w - R}{P^w - p}) \text{ for } p \in [R, p^{\max}] \tag{7}$$

where $p^{\max} = P^w(1 - e^{-\theta}) + e^{-\theta}R$. As θ rises, there are more traders relative to farmers, and the upper end of the distribution rises. The price distribution with higher values of θ first order stochastically dominates distributions with the lower ones. This makes intuitive sense as more competition to buy from the farmers will raise prices.

Together equations (5) and (6) above give us the equilibrium. Depending on the values of the primitive parameters there are four possible equilibrium configurations, all depicted in Figures 1a- 1d. Figures 1a and 1b show the equilibrium outcomes when $R < 1/\alpha$ and farmers specialize in the staple unless there is enough intermediation. In Figures 1c and 1d, $R > 1/\alpha$, so that farmers will produce the intermediated good even if there is no intermediation.

In Figure 1a there is a unique equilibrium with complete specialization in the staple good. $\theta_{\min} > \theta(1)$, and $l(.)$ and $\theta(.)$ have only one intersection at the origin. The level of intermediation implied by the amount of export good produced by farmers falls short of the level of intermediation necessary to induce farmers to produce the corresponding amount of the output. This occurs when P^w is low, α is low (agriculture is inefficient) and κ, the cost of entry for traders, is high.

Multiple equilibria, depicted in Figure 1b, arise when $\theta_{\min} < \theta(1)$ and $R < \frac{1}{\alpha}$. In Figure 1b the farmers best response function, $l(\theta)$, and traders' free entry condition, $\theta(l)$, intersect three times implying three equilibria.

The two complete specialization equilibria are stable. If no farmer makes the export good, then no traders will enter and $\theta = 0$. Given no traders will enter, no farmers will make the export good. The other stable equilibrium is where farmers produce only the export good, $l(.) = 1$, and given this, the number of intermediaries who enter is enough for the farmers

no farmers will make the specialized good. Thus, this is always an equilibrium to choose to produce only the export good.

The equilibrium where farmers produce both goods is not stable. When $\alpha E(P) = 1$, both goods yield identical profits. Just enough traders enter to keep them indifferent between the production of either good, and given indifference, farmers produce just enough to keep entry at this indifference level. But this is a fragile equilibrium: small perturbations will move the economy to one of the two stable equilibria.

When $R > \frac{1}{\alpha}$, it is profitable to make the specialized good even if there are no intermediaries. Figures 1c and 1d show configurations of equilibria with complete specialization in the export good with and without intermediation. $l(\theta) = 1$ for all $\theta \geq 0$, and the level of intermediation in the unique equilibrium is given by $\theta(l = 1)$. As long as the level of intermediation implied by $l = 1$ is positive, i.e., $l_{\min} < 1$, then $\theta(l = 1) > 0$ and in the unique equilibrium the export good produced by farmers is sold to the intermediaries.

If $l_{\min} > 1$, then $\theta(l = 1)$ equals zero, and the intermediated good is sold locally at a fixed price R. Such an equilibrium with $\theta = 0$ and $l = 1$ is shown in Figure 1d. $l_{\min} > 1$ occurs if R and/or κ is high, i.e., if

$$\frac{\kappa}{(P^w - R)\alpha} > 1.$$

Figure 2 depicts the possible equilibrium outcomes for different values of the primitive parameters R and κ given P^w and α.

When $R < \frac{1}{\alpha}$ and κ is relatively low, whether or not farmers produce the export good depends on their beliefs about the prevailing level of intermediation. In region M, multiplicity of equilibria in the sense of Figure 1b is endemic. When κ becomes so high that farmers find it unprofitable to enter, none of the export good will be made. This is the semicircular region in Figure 2 labelled N for no production. This situation corresponds to Figure 1a. The boundary between region M and N is defined by

$\theta(1) = \theta_{\min}$. [8]

When R is above the cut-off level $\frac{1}{\alpha}$, the farmer's outside option for the export good is high enough so that the equilibrium with no production of the export good is eliminated. However, when $R > P^w - \frac{\kappa}{\alpha}$, the expected profits of intermediaries fall short of the entry cost: no traders enter and the export good is sold to the canning factory which pays R. This corresponds to the region which in Figure 2 is labelled $P - NI$ for *Production and No Intermediation*. Only in the triangular area, labelled $P - I$ for *Production and Intermediation*, is there a unique equilibrium where the specialized good is produced and intermediaries connect farmers to the world market. This case is depicted in Figure 1c.[9]

Having some idea now of when intermediation can connect farmers to the world market, we proceed to consider the effects of various parameter changes on the outcomes.

2 Comparative Statics

We have shown that depending on the values of the primitive parameters there may be multiple or unique equilibria. How small changes in the primitive parameters impact the equilibrium outcomes, i.e. level of intermediation and producer price, depends on what region these parameters belong to and what equilibrium we are in. Since there is no production in region N, and there is no intermediation in region P-NI, the comparative statics we consider are relevant only in regions P-I and M. We will then build on these results to better understand how policy could help overcome the coordination failure that leads to sub optimal outcomes.

[8] Recall that $\theta_{\min}$ is defined implicitly by $E(p/\theta_{\min}) = \frac{1}{\alpha}$ and that $\theta(1) = \ln\left(\frac{(P^w-R)\alpha}{\kappa}\right)$. Using the expression for $E(p)$ from equation (3) gives this boundary as the R and κ such that:

$$P^w(1-\left(\frac{\kappa}{(P^w-R)\alpha}\right))(1+\ln\left(\frac{(P^w-R)\alpha}{\kappa}\right))+R\left(\frac{\kappa}{(P^w-R)\alpha}\right)(1+\ln\left(\frac{(P^w-R)\alpha}{\kappa}\right)) = \frac{1}{\alpha}.$$

[9] We assume P^w is exogenously given as the home country is small. However, if the home country is large, its entry into production would reduce the world price which in turn would make production and intermediation less likely (smaller), as the regions in Figure 5 are conditional on the world price.

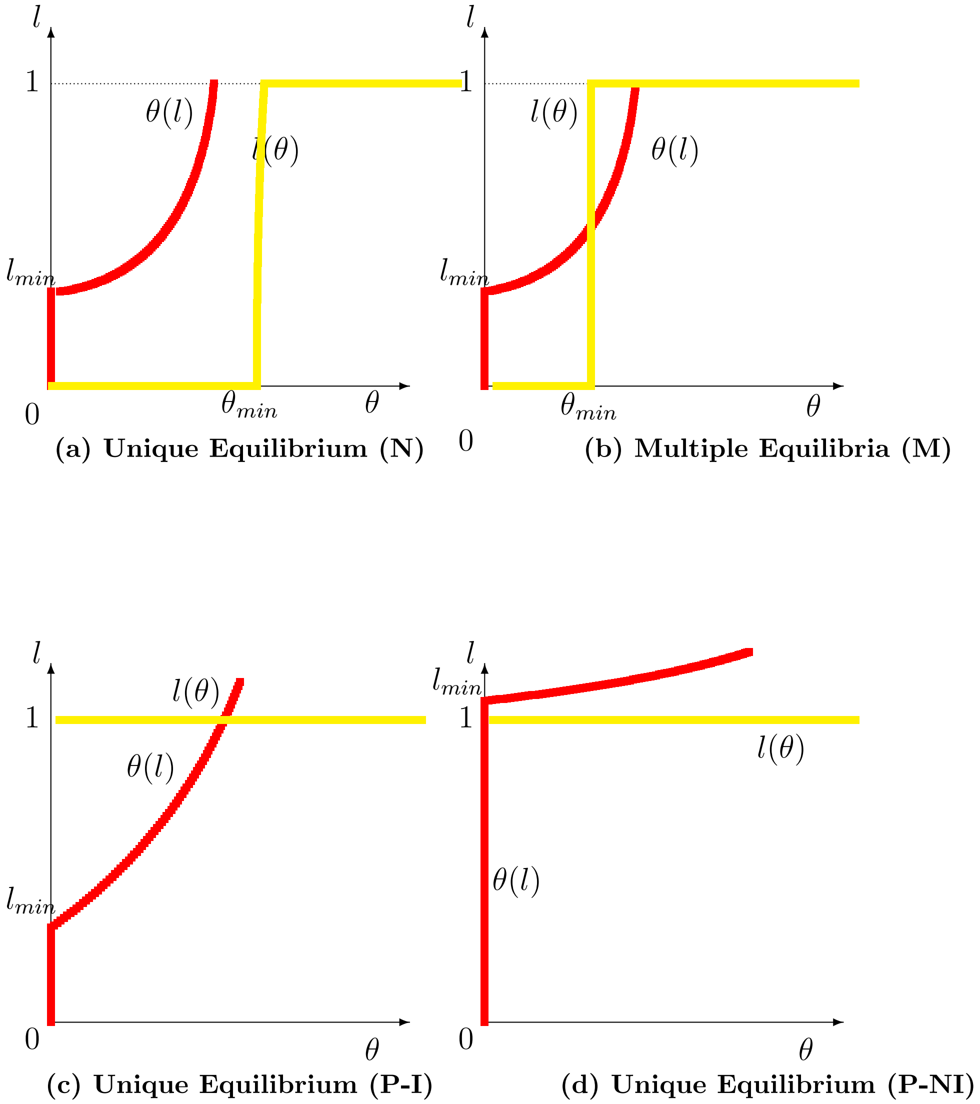

Figure 1: Types of equilibria.

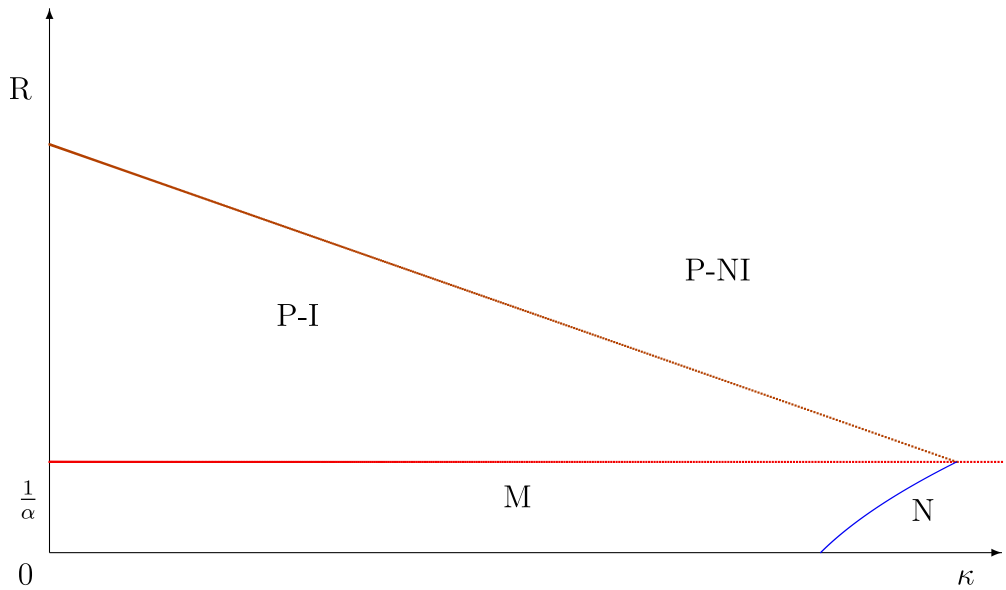

Figure 2: Equilibrium Types in the R and κ space for sufficiently high P^w and α

As noted earlier expected producer price is a convex combination of the world price, P^w and the farmers reservation price, R. Everything else constant, when the level of intermediation goes up the weight on P^w goes up and the corresponding weight on R goes down. Hence changes in the primitive parameters that increase the level of intermediation increase the producer price. A fall in κ, for example, encourages intermediary entry, thereby raising the expected price. In our setting, an improvement in agricultural productivity, α, not only raises farmers incomes directly, but also encourages more intermediation and via this effect raises the expected price farmers obtain. An increase in the world price, P^w, for example, raises the expected producer price both directly and through increasing the weight on the world price as intermediation also rises. As for the increase in the farmers reservation price, R, its direct effect on the producer price dominates the indirect effect of discouraging intermediation.

2.1 $E(p)$ and κ

Consider, for example, the effect of a decrease in the cost of entry for intermediaries, κ. For a given mass of traders, expected profits will turn positive as κ falls, which will induce entry. Entry, in turn will raise the competition at the farmers gate and raise the expected price paid by intermediaries. Entry will occur until the rise in this expected price just compensates for the lower κ. Thus, a fall in the entry costs raises the level of intermediation in equilibrium as well as the equilibrium expected producer price.

This can be seen in Figures 1b and 1c, where a lower κ will shift the $\theta(l)$ function to the right so that the equilibrium level of intermediation increases $\theta(l = 1)$. Using the expression for expected price from equation (3)

$$E(p) = P^w(1 - e^{-\theta}(1 + \theta)) + Re^{-\theta}(1 + \theta),$$

shows that the higher θ will reduce the weight on R, $e^{-\theta}(1+\theta)$, and increase the weight P^w, $1 - e^{-\theta}(1 + \theta)$, thereby raising the expected price which is a convex combination of R and P^w.

More formally,

$$\begin{aligned}
\frac{d\theta(l=1)}{d\kappa} &= \frac{d\ln(\frac{(P^w-R)\alpha}{\kappa})}{d\kappa} = -\frac{1}{\kappa} < 0 && (8)\\
\frac{dE(p|\theta(l=1))}{d\kappa} &= \frac{dE(p)}{d\theta}\frac{d\theta}{d\kappa} \\
&= (P^w-R)e^{-\theta}\theta\left(-\frac{1}{\kappa}\right) \\
&= -\frac{\theta}{\alpha} < 0 && (9)
\end{aligned}$$

where we take advantage of the fact that in the intermediation equilibrium $\theta(1) = \ln\left(\frac{(P^w-R)\alpha}{\kappa}\right)$ and therefore, $e^{-\theta} = \frac{\kappa}{(P^w-R)\alpha}$.

2.2 $E(p)$ and α

What about the effect of an increase in the productivity of the export good? At the existing level of intermediation with an increase in α each trader will make positive expected profits making entry for new intermediaries profitable. This in turn will raise the expected price and bring profits back in line with entry costs.

In Figures 1b and 1c, the $l(\theta)$ curve will shift to the left as farmers will be willing to make the export good at a lower level of intermediation, $\theta(l)$ will move to the right. In an equilibrium where risk-neutral farmers specialize in the export good only the shift in $\theta(l)$ affects the equilibrium outcomes: θ rises, raising $E(p)$.

In our model of agricultural trade with intermediation, productivity and producer price move in the same direction. Note, this implies that extension programs that aim to improve agricultural productivity not only will directly raise farmers output and income, but by encouraging intermediation they will let them obtain a higher expected price for their produce.[10]

More formally,

[10]This is in contrast with the literature that focuses on the adverse price effects of a productivity increase in competitive markets where the concern is that greater productivity would raise supply and depress the equilibrium price. In our model, the world price is fixed so that this is not an issue.

$$\frac{dE(p|\theta(l=1))}{d\alpha} = \frac{\kappa\theta}{\alpha^2} = \frac{\kappa \ln\left(\frac{\alpha(P^w - R)}{\kappa}\right)}{\alpha^2} > 0 \text{ for } \theta > 0. \quad (10)$$

2.3 $E(p)$ and R

In Figures 1b and 1c, an increase in the local price of the export good, R will shift the $l(\theta)$ curve to the left as farmers will be willing to make the export good at a lower level of intermediation. $\theta(l)$ will also move to the left. Only the latter affects the equilibrium where $l = 1$, and thus the equilibrium level of intermediation falls. While a higher value of R raises $E(p)$ through raising the lower bound on the price that a trader can offer, the fall in θ reduces competition among intermediaries and reduces $E(p)$.

Remark 1. *Note that this suggests that policies which provide a sure market for farmers could be a double edged sword: while they increase the reservation price, they discourage direct intermediation.*

Differentiating equation 3 with respect to R:

$$\begin{aligned}
\frac{dE(p|\theta(l=1))}{dR} &= e^{-\theta}(1+\theta) - (P^w - R)(-\theta)\, e^{-\theta}\frac{d\theta}{dR} \\
&= e^{-\theta}(1+\theta) - (P^w - R)(-\theta)\, e^{-\theta}\frac{-1}{P^w - R} \\
&= e^{-\theta}(1+\theta) - \theta e^{-\theta} = e^{-\theta} = \frac{\kappa}{\alpha(P^w - R)} > 0. \quad (11)
\end{aligned}$$

Equation (11) shows that the former effect dominates the latter, and the expected price goes up together with R. It also shows that the marginal effect of R on the expected price is decreasing in κ. In other words, a change in the farmers' outside option has little effect on the expected price when entry cost for traders is relatively low. This suggests that the lack of a local market for the intermediated good is important in economies with high entry costs for traders, i.e. communities with poor road conditions or landlocked economies. In the economies with easy access to farmers, the value of the outside option or the local market for the intermediated good plays a small role as competition among traders is sufficient to sustain a high expected producer price.

2.4 $E(p)$ and P^w

In Figures 1b and 1c, an increase in P^w will shift the $\theta(l)$ curve to the right, raising the equilibrium θ. A rise in P^w raises $E(p)$ directly, as well as through increasing θ. To do the comparative statics more formally differentiate the equation (3) with respect to P^w:

$$\begin{aligned}
\frac{dE(p|\theta(l=1))}{dP^w} &= \frac{\partial E(p)}{\partial P^w} + \frac{\partial E(p)}{\partial \theta}\frac{\partial \theta}{\partial P^w} \\
&= \left(1 - e^{-\theta}(1+\theta)\right) + \left(-(P^w - R)\left(-e^{-\theta}(1+\theta) + e^{-\theta}\right)\frac{d\theta}{dP^w}\right) \\
&= 1 - e^{-\theta}(1+\theta) - (P^w - R)\left(-e^{-\theta}\theta\right)\frac{d\theta}{dP^w} \\
&= 1 - e^{-\theta}(1+\theta) + (P^w - R)e^{-\theta}\theta\frac{1}{P^w - R} \\
&= 1 - e^{-\theta} > 0 \text{ for } \theta > 0, \qquad (12)
\end{aligned}$$

where we take advantage of the fact that $\frac{d\theta}{dP^w} = \frac{1}{P^w - R}$.

The effect of changes in the world price deserves special attention as it connects the model to the observable outcomes. Empirical studies, e.g. Fafchamps and Hill, 2008, find that the pass through of the changes in world commodity price to the producer prices is only partial. They propose that this happens because when world price goes up new traders enter and dissipate the profits increasing the search cost. Our model on the contrary predicts that entry of new intermediaries in response to changes in world price of the export good is needed to facilitate price transmission.

Proposition 3.

(i) The long run elasticity of the farmers' expected price with respect to the world price is larger than that in the short run.

(ii) The short run elasticity is less than unity for $R > 0$, and equals unity for $R = 0$. As the long run elasticity exceeds the short run one, the long run elasticity exceeds unity for low enough values of R. More generally, the long run elasticity is greater than unity when the prevailing level of intermediation,θ, is greater than $\frac{R}{P^w - R}$. This happens when the the profits of a trader who posts price R and gets to intermediate the good are high relative to the sunk cost of intermediation , i.e. when α, P^w are high,

and/or κ, R are low.

(iii) A unit increase in the world price never fully passes through into the expected price. In the long run $\frac{dE(p)}{dP^w} = \left[1 - e^{-\theta}\right] < 1$, *and in the short run* $\frac{\partial E(p)}{\partial P^w} = (1 - e^{-\theta}(1+\theta)) < 1$ *so that the extent of pass through in both the long and the short run are positively related to the level of intermediation.*

Proof. Using 12, the short run elasticity is given by

$$\begin{aligned}\frac{\partial E(p)}{\partial P^w}\frac{P^w}{E(p)} &= (1 - e^{-\theta} - e^{-\theta}\theta))\frac{P^w}{E(p)} \\ &= \frac{(1 - e^{-\theta}(1+\theta))P^w}{P^w(1 - e^{-\theta}(1+\theta)) + Re^{-\theta}(1+\theta)},\end{aligned}$$

which is unity when $R = 0$. It is less than unity when R is positive. The long run elasticity is given by

$$\begin{aligned}&\frac{dE(p)}{dP^w}\frac{P^w}{E(p)} \\ &= \left[\frac{\partial E(p)}{\partial P^w} + \frac{\partial E(p)}{\partial \theta}\frac{\partial \theta}{\partial P^w}\right]\frac{P^w}{E(p)} \\ &= \left(1 - e^{-\theta}\right)\frac{P^w}{E(p)}.\end{aligned}$$

The long run elasticity is more than the short run one as $\frac{\partial E(p)}{\partial \theta}\frac{\partial \theta}{\partial P^w} > 0$. When the world price rises, intermediaries enter and this drives up the price obtained by farmers.

The fact that the long run elasticity is greater than unity when the prevailing level of intermediation $\theta < \frac{R}{P^w - R}$ can be easily seen by considering when the $\frac{dE(p)}{dP^w}\frac{P^w}{E(p)} > 1$ in equation (13)[11].

□

[11] The long run elasticity is given by $\frac{\left[1-e^{-\theta}\right]P^w}{E(p)} = \frac{\left[1-e^{-\theta}\right]P^w}{P^w(1-e^{-\theta}) - e^{-\theta}(P^w\theta + R(1+\theta))}$. Hence, $\frac{dE(p)}{dP^w}\frac{P^w}{E(p)} > 1$ when $e^{-\theta}\left(P^w\theta - R(1+\theta)\right) > 0$, which happens when the prevailing level of intermediation, θ, is greater than $\frac{R}{P^w - R}$.

3 Policy Implications

In our model the interaction of several market frictions can prevent the efficient allocation of resources. In fact, the economy can end up specializing in the commodity in which it has a comparative disadvantage. In what follows, we take the existence of these frictions as given and look at the efficacy of alternative policy instruments and their welfare implications. We consider a production subsidy, policies reducing intermediation costs, lump sum taxes and transfers, and the creation of a cooperative that guarantees the farmer a fixed price for his strawberries.

Here we focus on policies that are applicable when primitive parameters are such that multiple equilibria are endemic, i.e. region M in Figure 1. We ask how one can move economy from the *bad* equilibrium, where farmers sub-optimally specialize in the staple good, to the *good* equilibrium, where strawberries are produced for export. Both a production subsidy and a marketing board that buys strawberries eliminate multiplicity of equilibria by making specialization in the export good the dominant strategy for the farmers. However, as we show below, they have different implications for the level of intermediation, producer prices and welfare.

3.1 Eliminating the Bad Equilibrium

If we can ensure that it is a dominant strategy for the farmer to produce the export good, then the bad equilibrium is eliminated. We could raise the farmer's pay-offs from making the export good by offering a production subsidy or a price support in the form of an export board willing to pay a sufficiently high fixed price for the export good.

A Production Subsidy

Consider a production subsidy per unit of output of the export good. As domestic agents consume only the staple, welfare is the income of farmers (from production and the production subsidy) plus that of traders and net government revenue, NGR.

$$W = \alpha E(p)l^* + \alpha sl^* + (1 - l^*) + (\pi(p) - \kappa) + NGR$$

Traders make zero expected profits so that their contribution to welfare, $\pi(p) - \kappa$, is zero. NGR equals expenditure on the subsidy or $-\alpha s l^*$. The subsidy is a transfer between farmers and the government so that it washes out in welfare in terms of its direct effect. Thus, welfare boils down to the earnings of farmers, net of the production subsidy.

$$W = \alpha E(p) l^* + (1 - l^*)$$

where p denotes the price obtained by the farmer.

Suppose the government offers a per unit subsidy slightly above $s = \frac{1}{\alpha}$, say $\frac{1}{\alpha} + \epsilon$. Then farmers will specialize in the export good as even with no traders, farmers' expected income from making the export good exceeds that from making the staple: $\alpha(\frac{1}{\alpha} + \epsilon) > 1$. Knowing that farmers will produce the export good, traders will enter. Farmers who are approached by traders sell to the highest bidder, while farmers who meet no traders receive $R \geq 0$ for their output.

It is easy to see in Figure 1b, that such a subsidy will create a unique equilibrium with all farmers producing the export good. When such a subsidy induces a move from the bad equilibrium to the good equilibrium welfare increases as $\alpha E(p) > 1$. For example, introducing a production subsidy in an economy where farmers produce a staple but have a comparative advantage in strawberries, as in region M in Figure 2, will increase social welfare.

What about the other regions? In region N, farmers have a comparative advantage in the staple and specialize in it. Hence subsidizing production of strawberries reduces overall welfare. If the economy is in $P-I$ or $P-NI$ farmers always specialize in the strawberries and the production subsidy will just create a transfer between the government and the farmers with no real effects on the producer price.

Proposition 4. *A per unit production subsidy greater than or equal to $1/\alpha$ can move the equilibrium to the one with intermediation and raise welfare if the economy is in region M. It will lower welfare if the economy is in region N, and have no effect otherwise.*

An Export Board

What would be the effect of an export board that commits to purchase strawberries from the farmer at a fixed price, R, when multiple equilibria persist? If the board offers a price less than $\frac{1}{\alpha}$, multiplicity remains. An export board that pays a price $R \geq \frac{1}{\alpha}$ per unit of the export good ensures that farmers specialize in the export good and eliminates the multiplicity of equilibria. When farmers produce and sell the export good to intermediaries, introduction of an export board which raises the farmers reservation price lowers the level of intermediation but still raises the expected producer price.

With an export board in place, the social welfare function becomes

$$W = \begin{cases} \alpha E(p) + \alpha(P^g - R)e^{-\theta} \text{ if } \alpha(P^w - R) > \kappa, \text{ i.e. } \theta > 0 \\ \alpha P^g \text{ if } \alpha(P^w - R) \leq \kappa, \text{ i.e. } \theta = 0. \end{cases} \tag{13}$$

When the level of intermediation is positive, i.e., $\alpha(P^w - R) > \kappa$, social welfare is the sum of the farmer's expected earnings, $\alpha E(p)$, and the board's profits when the farmer sells to it, $\alpha(P^g - R)e^{-\theta}$.[12] When intermediaries do not enter, i.e. $\alpha(P^w - R) \leq \kappa$, social welfare is determined by revenues of the export board and is constant at αP^g**.** Welfare increases in R as long as the equilibrium level of intermediation is positive. This can be seen by differentiating the welfare function with respect to R.

$$\frac{dW}{dR} = \alpha \left[\frac{dE(p)}{dR} - e^{-\theta} - (P^g - R)e^{-\theta}\frac{d\theta}{dR} \right]. \tag{14}$$

Substituting for

$$\frac{dE(p)}{dR} = e^{-\theta}$$

in 14 gives

$$\begin{aligned} \frac{dW}{dR} &= \alpha \left[-(P^g - R)e^{-\theta}\frac{d\theta}{dR} \right] \\ &= \alpha \left[\frac{(P^g - R)}{(P^w - R)} e^{-\theta} \right] \end{aligned}$$

[12] Recall that a farmer only sells to the board if there is no match with a trader which occurs with probability $e^{-\theta}$.

$$= \frac{\kappa(P^g - R)}{(P^w - R)^2} > 0 \text{ if } P^g - R > 0 \tag{15}$$

where we use the fact that $e^{-\theta} = \frac{\kappa}{\alpha(P^w - R)}$.

The optimal value of R depends whether the board or the intermediaries are more efficient. We say that intermediaries are more efficient than the board when $\alpha(P^w - P^g) > \kappa$, or the cost of intermediation is less than the loss in revenue from selling the export good at P^g rather than P^w. If the export board is more efficient than the intermediaries, $\alpha(P^w - P^g) \leq \kappa$, the optimal price at which the board should purchase from the farmer is $R = P^g$. If intermediaries are more efficient, $\alpha(P^w - P^g) \leq \kappa$, then any R at or above $P^w - \frac{\kappa}{\alpha}$ is optimal.

To see this, note that as R rises, the level of intermediation falls, while social welfare increases. When R increases to the point that $\kappa \leq \alpha(P^w - R)$ intermediation becomes unprofitable and welfare is constant at αP^g. If intermediation remains positive at $R = P^g$ then according to 15 the optimal price for the export board to offer to the farmers is P^g. If intermediation becomes unprofitable before R reaches P^g, i.e., $\alpha(P^w - P^g) \leq \kappa$, then welfare is no longer affected by R, so it is optimal to set R at or above $P^w - \frac{\kappa}{\alpha}$ which eliminates intermediation and implies welfare of αP^g.

Proposition 5. *If $\alpha(P^w - P^g) > \kappa$, it is optimal to set $R = P^g$. If $\alpha(P^w - P^g) \leq \kappa$, then any R at or above $P^w - \frac{\kappa}{\alpha}$ is optimal.*

What is the economic intuition behind this result? When $\alpha(P^w - P^g) \leq \kappa$ intermediaries waste more resources than the board and hence it is socially optimal for all farmers to sell their output to the board. When intermediaries are more efficient than the board, $\alpha(P^w - P^g) > \kappa$, profits of intermediaries are dissipated by entry, while the positive profits of the board when $P^g - R > 0$ are included in the social welfare. Hence we want to maximize the joint income of farmers and the board. An increase in R raises the earnings of the farmer by $e^{-\theta}$ and reduces the profits of the board by $e^{-\theta}\frac{P^w - P^g}{P^w - R}$. When R is less than P^g the marginal cost to the board is smaller than the marginal increase in the producer price. When R is exactly equal to P^g, the marginal increase in the producer price is exactly equal to the decrease in the revenues of the board. Hence it is optimal to set R equal to P^g as long as there is intermediation.

Reducing entry costs in the presence of an export board.

While social welfare increases in R, a higher value of R reduces entry of intermediaries which puts negative pressure on the price producers obtain. In this section we consider the effect of changing the cost of entry for intermediaries in the presence of the export board. We ask if a reduction in the cost of entry for intermediaries, both exogenous or induced by government policy, improves welfare.

In equilibria where the export good is produced, a reduction in the cost of intermediation increases competition among traders and increases the producer price. Reducing the cost of intermediation does not directly affect the decision of farmers to produce, and therefore does not eliminate the no production equilibrium. When no export good is produced, no intermediaries enter.

In the presence of an export board and a positive level of intermediation, welfare for a unit mass of farmers is given by 13. Formally, the change in welfare due to an exogenous change in κ is given by:

$$\begin{aligned}\frac{dW}{d\kappa} &= \alpha\frac{dE(p)}{d\kappa} + \alpha(P^g - R)\frac{de^{-\theta}}{d\kappa} \\ &= \left[-\theta + \frac{(P^g - R)}{(P^w - R)}\right] \\ &= \left[\frac{-\theta(P^w - R) + (P^g - R)}{(P^w - R)}\right] \\ &= -\theta + \frac{P^g - R}{P^w - R}. \end{aligned} \tag{16}$$

A reduction in the cost of entry, κ, has two effects on social welfare. First, it increases the income of farmers. Second, the probability of not meeting a trader and selling to the board, $e^{-\theta}$, falls. When $P^g - R > 0$, which of the two effects dominates depends on the prevailing level of intermediation, as seen in 16. When R is set optimally the effect of an exogenous decrease in κ is unequivocal. With $R = P^g$ profits of the export board are exactly zero and no longer play a role in welfare, and a decrease in κ is welfare improving.

If intermediation is not efficient, i.e., $\alpha(P^w - P^g) > \kappa$, then R is set so that intermediation vanishes and θ is zero. In this case, κ does not affect welfare. This is summarized in the next proposition:

Proposition 6. *If government is less efficient than intermediaries, and sets R optimally, there will be intermediation, and an exogenous fall in entry costs raises welfare. If government is more efficient than intermediaries, and sets R optimally, there will be no intermediation and an exogenous fall in entry costs has no effect on welfare.*

If the entry cost is reduced by a government subsidy rather than being exogenous, then we need to add the cost of the subsidy to welfare. Let $\kappa = \kappa^0 - s$ where κ^0 is the initial cost of intermediation and s is the amount of the subsidy. Then,

$$W = \begin{cases} \alpha E(p) + \alpha(P^g - R)e^{-\theta} - s\theta \text{ if } \alpha(P^w - R) > \kappa \text{ , i.e. } \theta > 0 \\ \alpha P^g \text{ if } \alpha(P^w - R) \leq \kappa \text{ , i.e. } \theta = 0. \end{cases} \tag{17}$$

To determine if there exists a welfare maximizing tax or subsidy scheme differentiate 17 with respect to s.

As $\frac{d\kappa}{ds} = -1$,

$$\begin{aligned} \frac{d(s\theta)}{ds} &= \theta + s\frac{d\theta}{d\kappa}\frac{d\kappa}{ds} \\ &= \theta + \left(\frac{s}{\kappa}\right). \end{aligned} \tag{18}$$

From equation (17) and using equations (16) and (18) we get:

$$\begin{aligned} \frac{dW}{ds} &= \frac{dW}{d\kappa}\frac{d\kappa}{ds} - \frac{d(s\theta)}{ds} \\ &= \left[-\theta + \frac{P^g - R}{P^w - R}\right](-1) - \theta - \left(\frac{s}{\kappa}\right) \\ &= -\left[\frac{P^g - R}{P^w - R}\right] - \left(\frac{s}{\kappa}\right). \end{aligned} \tag{19}$$

Thus, a subsidy cannot raise welfare as long as $(P^g - R) > 0$.

At the optimum, $\frac{dW}{ds} = 0$. Setting $\kappa = \kappa_0 - s$, and solving for the optimal s from equation (19) the optimal level of the subsidy, s^* is given by:

$$s^* = -\frac{\kappa_0 (P^g - R)}{[P^w - P^g]}. \tag{20}$$

When intermediaries are more efficient than the board, and R is set optimally at P^g it is optimal to neither subsidize nor tax the entry of intermediaries, $s^* = 0$. When R is not chosen optimally and the board makes positive profits, it is optimal to tax the entry of intermediaries, i.e., the optimal subsidy is negative. In this case intermediaries do not internalize the effect of their entry on the profits of the board, and the tax on intermediaries corrects the externality. Proposition 7 summarizes the results.

Proposition 7. *When intermediaries are more efficient than the board and R is not set optimally, then it is optimal to tax entry. If R is set optimally, there is no case for an entry tax or subsidy.*

4 Conclusion

Our model provides an alternative rationale as to why developing countries specialize in the traditional goods despite the presence of more lucrative options. In our model we present how, even if farmers are more efficient in producing an export good, they may not specialize in it. The lack of enforceable contracts between intermediaries and producers gives rise to multiple equilibria. When a large number of people produce the intermediated good, markets function reasonably well. Otherwise the economy ends up specializing in the staple good instead of the export good.

Our model reveals a number of novel results. First it suggests that there may be some simple solutions to these problems even if the government is not able to resolve the core issue (the lack of enforceable contracts) responsible for the problem. A temporary production subsidy, or a marketing board that ensures a minimum price to the farmer can help an economy remove the bad equilibrium without intermediation. With a marketing board the social welfare is maximized when the board offers the farmer the highest price it can without making losses. [13]

Our work also suggests a new reason for promoting agricultural extension programs that aim to improve agricultural productivity. Not only do

[13] In the presence of risk aversion, as shown in the Appendix, these policies are shown to have greater effect on producer price and welfare, as there are additional production effects that amplify the effects of such policies.

they directly raise farmers output and income, but also encourage intermediation thus raising the farmers' expected price. The results we obtain also shed light on why increases in world prices may not feed back fully into prices obtained by farmers (as has been noted for coffee), especially in the short run.

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A Appendix 1: The Expected Price

Lemma 3. *Given the level of intermediation, θ, the expected price is given by*

$$\begin{aligned} E(p) &= \sum_{k=0}^{\infty} Q_k \int_{R}^{p_{\max}} p dG_k(p) \\ &= P^w - e^{-\theta}(P^w - R)(1+\theta) \\ &= P^w \left(1 - e^{-\theta}(1+\theta)\right) + Re^{-\theta}(1+\theta). \end{aligned} \tag{21}$$

As $0 < e^{-\theta}(1+\theta) < 1$,[14] *the expected price is also a convex combination of the world price and R.*

Proof. By definition, the expected value of the price the farmer gets is

$$\begin{aligned} E(p) &= \sum_{k=0}^{\infty} Q_k E_k(p) \\ &= Q_0 R + \sum_{k=1}^{\infty} Q_k [\int_R^{p_{\max}} p g_k(p) dp] \\ &= Q_0 R + \sum_{k=1}^{\infty} Q_k [\int_R^{p_{\max}} pk[F(p)]^{k-1} f(p) dp]. \end{aligned}$$

Recall that

$$Q_k = \frac{\theta^k}{k!} e^{-\theta}, G_k(p) = [F(p)]^k, g_k(p) = k[F(p)]^{k-1} f(p)$$

$$\begin{aligned} p^{\max} &= P^w(1 - e^{-\theta}) + e^{-\theta} R \\ \frac{P^w - R}{P^w - p^{\max}} &= \frac{P^w - R}{P^w - [P^w(1 - e^{-\theta}) + e^{-\theta} R]} \\ &= e^{\theta} \end{aligned}$$

$$F(p) = \frac{1}{\theta} \ln(\frac{P^w - R}{P^w - p}) \ for \ R \le p \le p^{max}$$

[14] $e^{\theta} > 1 + \theta$ so $\frac{1}{1+\theta} > e^{-\theta}$ or $1 > e^{-\theta}(1+\theta)$.

$$
\begin{aligned}
f(p) &= \frac{1}{\theta}(\frac{P^w-p}{P^w-R})\left(\frac{P^w-R}{(P^w-p)^2}\right) \ for\ R\leq p\leq p^{max} \\
&= \frac{1}{\theta}\left(\frac{1}{(P^w-p)}\right) \ for\ R\leq p\leq p^{max} \\
f(R) &= \frac{1}{\theta} \\
f(p^{\max}) &= \frac{1}{\theta}(\frac{P^w-(P^w(1-e^{-\theta})+e^{-\theta}R)}{P^w-R}) \\
&= \frac{e^{-\theta}}{\theta}.
\end{aligned}
$$

Now we are ready to show that

$$
Q_0R+\sum_{k=1}^{\infty}Q_k[\int_R^{p_{\max}} pk[F(p)]^{k-1}f(p)dp] = P^w\left(1-e^{-\theta}(1+\theta)\right)+Re^{-\theta}(1+\theta).
$$

First we obtain the expected price when k traders show up:

$$
\begin{aligned}
E_k(p) &= \int_R^{p_{\max}} pg_k(p)dp \\
&= k\int_R^{p_{\max}} pf(p)\left[F(p)\right]^{k-1}dp \\
&= \frac{k}{\theta^k}\int_R^{p_{\max}}[\ln(\frac{P^w-R}{P^w-p})]^{k-1}\frac{p}{P^w-p}dp \text{ for } k\geq 1
\end{aligned}
\tag{22}
$$

Then we take the expectation over all possible k.

We start by solving for the indefinite integral, a key part of $E_k(p)$.

$$
\int[\ln(\frac{P^w-R}{P^w-p})]^{k-1}\frac{p}{P^w-p}dp. \tag{23}
$$

To do so we change variables. Let $x=\ln(\frac{P^w-R}{P^w-p})$.

$$
\begin{aligned}
e^x &= \frac{P^w-R}{P^w-p} \\
&\implies P^w-p=e^{-x}(P^w-R) \\
&\implies p=P^w-e^{-x}(P^w-R).
\end{aligned}
\tag{24}
$$

This gives p in terms of x.To change variables we note

$$
dp=e^{-x}(P^w-R)dx. \tag{25}
$$

Substituting for p from (24) we get

$$\begin{aligned}\frac{p}{P^w - p} &= \frac{P^w - e^{-x}(P^w - R)}{e^{-x}(P^w - R)} \\ &= \frac{P^w}{e^{-x}(P^w - R)} - 1. \end{aligned} \tag{26}$$

Using equations (24),(25), and (26) we can rewrite the integral in equation (23) as

$$\begin{aligned} \int x^{k-1}[e^x \frac{P^w}{(P^w - R)} - 1]e^{-x}(P^w - R)dx = \\ = P^w \int x^{k-1}dx - (P^w - R) \int e^{-x}x^{k-1}dx = \\ = P^w \frac{x^k}{k} - (P^w - R)\left[x^{k-1}e^{-x}(-1) - (k-1)\int (-1)e^{-x}x^{k-2}dx\right] = \\ = P^w \frac{x^k}{k} + (P^w - R)e^{-x}\,(k-1)!\left[\frac{x^{k-1}}{(k-1)!} + \frac{x^{k-2}}{(k-2)!} + .. + 1\right] = \\ = P^w \frac{x^k}{k} + (P^w - R)(k-1)!e^{-x}[\sum_{j=0}^{k-1} \frac{x^j}{j!}] \end{aligned} \tag{27}$$

Substituting back to obtain the expression above in terms of p

$$\int_R^{p_{\max}} [\ln(\frac{P^w - R}{P^w - p})]^{k-1} \frac{p}{P^w - p} dp = (1) + (2)$$

$$\begin{aligned} (1) &= \frac{P^w}{k}[\ln(\frac{P^w - R}{P^w - p})]^k|_R^{p^{\max}} \\ &= \frac{P^w}{k}[\ln(\frac{P^w - R}{P^w - p^{\max}})]^k - \frac{P^w}{k}[\ln(\frac{P^w - R}{P^w - R})]^k \\ &= \frac{P^w}{k}[\ln(e^\theta)]^k - 0 \\ &= \frac{P^w}{k}\theta^k \end{aligned}$$

and

$$
\begin{aligned}
(2) &= (P^w-R)(k-1)!\frac{P^w-p}{P^w-R}[\sum_{j=0}^{k-1}\frac{[\ln(\frac{P^w-R}{P^w-p})]^j}{j!}]|_R^{p_{\max}} \\
&= (k-1)!\{(P^w-R)e^{-\theta}[\sum_{j=0}^{k-1}\frac{[\ln(e^{\theta})]^j}{j!}] - \underbrace{(P^w-R)[1-\sum_{j=0}^{k-1}\frac{[\ln(\frac{P^w-R}{P^w-R})]^j}{j!}]}_{(P^w-R)}\} \\
&= (k-1)!(P^w-R)\{e^{-\theta}[\sum_{j=0}^{k-1}\frac{\theta^j}{j!}]-1\} \\
&= (P^w-R)(k-1)!\{e^{-\theta}\sum_{j=0}^{k-1}\frac{\theta^j}{j!}-1)\}
\end{aligned}
$$

where we use the fact that $P^w - p^{\max} = e^{-\theta}(P^w - R)$. Next we find $E_k(p)$ for $k > 1$ for a given θ.

$$
\begin{aligned}
E_{k\geq 1}(p|\theta) &= \frac{k}{\theta^k}\int_R^{p_{\max}} \frac{p}{P^w-p}[\ln(\frac{P^w-R}{P^w-p})]^{k-1}dp \\
&= \frac{k}{\theta^k}[(1)+(2)] \\
&= \frac{k}{\theta^k}(P^w\frac{\theta^k}{k}+(P^w-R)(k-1)!\{e^{-\theta}\sum_{j=0}^{k-1}\frac{\theta^j}{j!})-1\}) \\
&= P^w+(P^w-R)\frac{(k)!}{\theta^k}\{e^{-\theta}\sum_{j=0}^{k-1}\frac{\theta^j}{j!}-1\}
\end{aligned}
$$

Hence the expected price conditional on at least one trader showing up is as follows:

$$
\begin{aligned}
\sum_{k=1}^{\infty}Q_kE_k(p) &= \sum_{k=1}^{\infty}\frac{\theta^k}{k!}e^{-\theta}\left[P^w+(P^w-R)\frac{k!}{\theta^k}(e^{-\theta}\sum_{j=0}^{k-1}\frac{\theta^j}{j!}-1)\right] \\
&= \sum_{k=1}^{\infty}\frac{\theta^k}{k!}e^{-\theta}P^w+(P^w-R)e^{-\theta}\sum_{k=1}^{\infty}(e^{-\theta}\sum_{j=0}^{k-1}\frac{\theta^j}{j!}-1) \\
&= e^{-\theta}P^w(e^{\theta}-1)+(P^w-R)e^{-\theta}\left[\sum_{k=1}^{\infty}(e^{-\theta}\sum_{j=0}^{k-1}\frac{\theta^j}{j!}-1)\right] \\
&= e^{-\theta}P^w(e^{\theta}-1)+(P^w-R)e^{-\theta}[-\theta]
\end{aligned}
$$

where we use the fact that $\sum_{k=1}^{\infty}(e^{-\theta}\sum_{j=0}^{k-1}\frac{\theta^j}{j!}-1)=-\theta$. This can be verified as follows:

$$\begin{aligned}
\sum_{k=1}^{\infty}(e^{-\theta}\sum_{j=0}^{k-1}\frac{\theta^j}{j!}-1) &= \sum_{k=1}^{\infty}(e^{-\theta}(\sum_{j=0}^{\infty}\frac{\theta^j}{j!}-\sum_{j=k}^{\infty}\frac{\theta^j}{j!})-1) \\
&= \sum_{k=1}^{\infty}(e^{-\theta}(e^{\theta}-\sum_{j=k}^{\infty}\frac{\theta^j}{j!})-1) \\
&= \sum_{k=1}^{\infty}((1-e^{-\theta}\sum_{j=k}^{\infty}\frac{\theta^j}{j!})-1) \\
&= -e^{-\theta}\sum_{k=1}^{\infty}\sum_{j=k}^{\infty}\frac{\theta^j}{j!} \\
&= -e^{-\theta}\sum_{j=1}^{\infty}\sum_{k=1}^{j}\frac{\theta^j}{j!}
\end{aligned}$$

The above change in summations can be verified by writing out terms in each one and noting that the first term in the former corresponds to the last term in the latter. Thus

$$\begin{aligned}
\sum_{k=1}^{\infty}(e^{-\theta}\sum_{j=0}^{k-1}\frac{\theta^j}{j!}-1) &= -e^{-\theta}\sum_{j=1}^{\infty}\frac{\theta^j}{j!}(\sum_{k=1}^{j}1) \\
&= -e^{-\theta}\sum_{j=1}^{\infty}\frac{\theta^j}{(j-1)!} \\
&= -e^{-\theta}\theta\sum_{j=1}^{\infty}\frac{\theta^{j-1}}{(j-1)!} \\
&= -\theta.
\end{aligned}$$

Finally, the first moment of price is

$$\begin{aligned}
E(p) &= Q_0R+\sum_{k=1}^{\infty}Q_kE_k(p) \\
&= e^{-\theta}R+P^we^{-\theta}(e^{\theta}-1)+e^{-\theta}(P^w-R)(-\theta) \\
&= e^{-\theta}R+P^w-P^we^{-\theta}-\theta e^{-\theta}(P^w-R) \\
&= -e^{-\theta}(P^w-R)+P^w-\theta e^{-\theta}(P^w-R)
\end{aligned}$$

$$= \quad P^w - e^{-\theta}(P^w - R)(1+\theta).$$

□

B Appendix 2: Risk Averse Farmers

When farmers are risk neutral, they choose to produce the crop with the higher expected payoff. When they are risk averse, they could choose to produce both goods to help insure themselves. This is consistent with anecdotal evidence on small agricultural households.

Risk aversion affects the farmers' side of the model. A risk averse farmer with a concave utility function $U(\cdot)$, defined over the units of the numeraire good, maximizes his expected utility by allocating his labor endowment between the production of the two goods given the distribution of prices:

$$\max_{l\in[0,1]} \left\{ e^{-\theta}U(l,R) + \sum_{k=1}^{\infty} \frac{e^{-\theta}\theta^k}{k!} \int_{p_{\min}}^{p_{\max}} U(l,\tilde{p})dG_k(p) \right\}$$

As in the risk neutral case, $G_k = [F(p)]^k$ denotes the CDF of the distribution of the maximum price when a farmer meets k traders. If l^* is the equilibrium output of the export good by each farmer, then the level of intermediation is given by $\theta(l^*) = \max\left\{\ln(\frac{(P^w-R)\alpha l^*}{\kappa}), 0\right\}$.

Multiplicity of equilibria persists in this set up. When farmers believe that no intermediaries will enter and the local price of the export good is low, they chose not to produce the export good at all so that no intermediation occurs. Two properties of the equilibrium when farmers are risk averse stand out relative to the case of risk neutral farmers. First, farmer does not specialize in the production of the export good as soon as the expected price exceeds the opportunity cost of specializing in the staple. He requires a premium for taking the risk of receiving a low price for the export good. Second, $l^*(\theta)$ is no longer a step function as farmers choose to diversify their output. As a consequence, policies can affect the allocation of labor across crops so that they have real effects on output. Unfortunately, analytical solutions with risk aversion are impossible and we rely on simulations for results.

Next we will use numerical examples to consider implications of a production subsidy and export board in the set up where farmers are risk averse.

B.0.1 Production Subsidy:

With risk aversion a production subsidy increases both the output of the export good and the level of intermediation in the good equilibrium. The production subsidy gives farmers a direct incentive to increase output. The increase in output, in turn, has a positive effect on the level of intermediation which again increases the expected producer price.

We simulate the equilibrium for different values of the parameters. The qualitative conclusions are similar across different sets of parameters so here we report the simulation for the CRRA utility function with relative risk aversion of 1.5 for the following parameter values: $P^w = 3, \alpha = 2, R = 0, \kappa = 1$. In this simulation we solve for the equilibrium level of intermediation and output by each farmer for a set of subsidy values from 0 to $\frac{1}{\alpha}$[15]. Figures 3 and 4 show that the output of the export good and the level of intermediation (on the y-axis) rise with the amount of the subsidy (on the x-axis). Until the farmer completely specializes in the export good, increases in the subsidy raise both the level of intermediation and the output of the specialized good. It is worth pointing out that the subsidy has no direct effect on the level of intermediation as it does not directly enter the expression for the level of intermediation 6. Increases in intermediation occur entirely via the equilibrium effect of increased output. Figure 5 depicts the farmer's utility as the subsidy rises. Note that utility rises faster before complete specialization than after. Farmers choose to make both goods because poor intermediation increases the risk of not being matched. A subsidy increases the production of the export good, which in turn induces more intermediation, which reduces the risk of making the export good and raises utility. There is also a direct effect of the subsidy on utility. Once specialization occurs, only the latter operates.

[15] Although we compute allocations for subsidies $\leq \frac{1}{\alpha} = .5$, the figure only contains values until .2. The rst of the outcomes were omitted because the specialization has occurred long before .5 is reached.

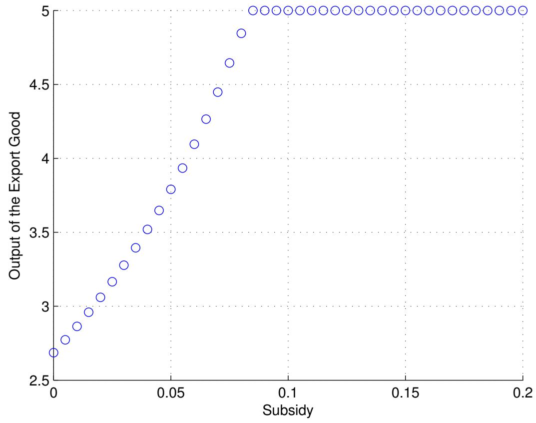

Figure 3: Output response to a subsidy.

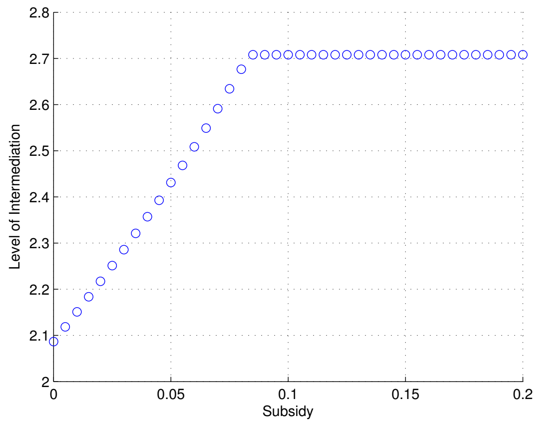

Figure 4: Intermediation and the subsidy.

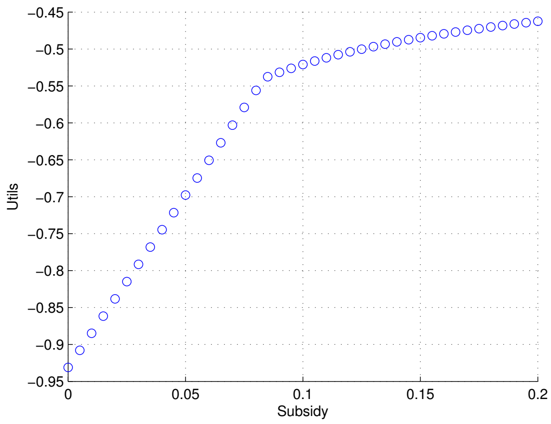

Figure 5: Utility as a function of the subsidy.

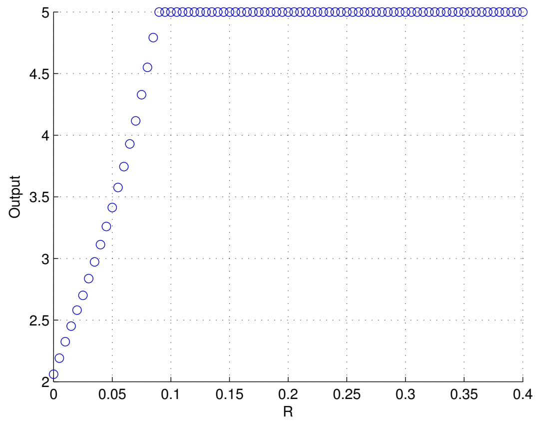

Figure 6: Response of output to R.

Export Board: Reservation price Figures 6, 7, 8 show how output, level of intermediation and farmer utility change in response to changes in the value of reservation price for the export good, respectively. Just as in the risk neutral case, when farmer is risk averse an increase in the farmer's reservation price has a direct effect of raising the expected price of the export good while reducing it through its affect on intermediation. Unless the farmer has already specialized in the export good, an increase in the expected price leads to a reallocation of labor from the production of the staple good to the production of the export good, which in turn increase the profit margin of traders and induces more trader entry. The equilibrium expected price rises as the direct effect of raising R dominates.

The simulations in figures 6, 7 show that until farmers specialize, labor allocated to the export good and intermediation levels both *increase* with R. With risk aversion, increase in R not only raises the expected price but also rises intermediation as long as the output of the export good is increasing. Once farmers have specialized in the export good, only the effect via the outside option operates and the level of intermediation starts falling. The farmer's utility continues to increase in R even after specialization has occurred, although at a slower rate than before specialization. [16]

[16] The simulation reported here is done for the same parameters as in the exercise with the subsidy.

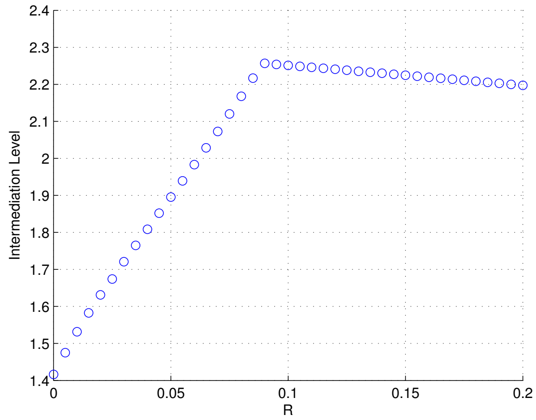

Figure 7: Response of intermediation to R.

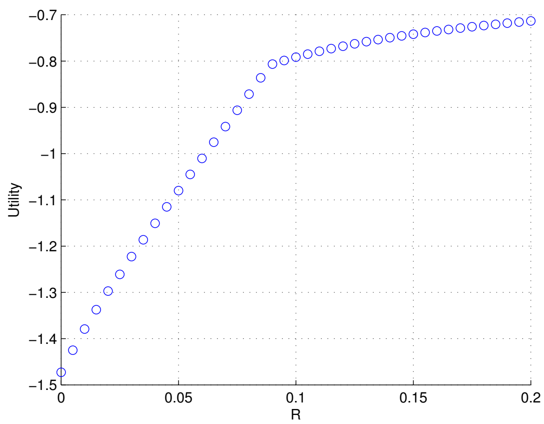

Figure 8: Response of farmer's utility to R.