Quality Observability and the Structure of Agricultural Supply Chains

Tara Mitchell

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Department of Economics

Trinity College Dublin

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Abstract

This paper presents a model of a supply chain for a good involving two stages of production. Effort must be exerted at both stages if a high-quality good is to be produced. Effort is not observable and the quality of the good is not perfectly observable. The model predicts that there will be a range of values of the price difference between high-quality and low-quality goods for which production of high-quality goods will occur with vertical integration but will not occur if the tasks are carried out by separate agents. The range of price values for which this occurs will be decreasing as the level of observability of quality increases and will disappear as quality becomes perfectly observable. The paper also presents some case studies of supply chains for various products in a number of developing countries that have characteristics which are consistent with the predictions of the model.

JEL codes: O13, Q13

1 Introduction

A low level of production of high-quality agricultural goods is a major problem for many developing countries. The World Development Report 2008, Agriculture for Development, highlighted the opportunities for farmers to increase their profits by supplying rapidly growing urban and export markets which demand goods of higher quality. In addition, the availability of better-quality food products which are more hygienic and higher in nutritional value could lead to improved health outcomes for consumers. This paper will investigate the relationship between the decision to produce high-quality goods and two important

characteristics of the product: the degree of observability of quality and the level of intermediation in the supply chain.

Supply chains for agricultural goods in most developed countries are characterised by a high level of integration. Farmers generally sell directly to processors or through agricultural cooperatives. Supply chains in many developing countries, on the other hand, tend to involve a large number of intermediaries, such as collectors, middlemen or brokers, who perform a variety of functions. It is possible that this higher level of intermediation could lead to a lower level of production of high-quality goods, especially if each actor in the supply chain must exert effort in order to maintain the quality of the good.

Not all quality attributes are easily observable and in some cases it is necessary to carry out tests in order to know whether or not a good is of high quality. A middleman may be unwilling to pay a farmer a high price for a good that may not be of high quality, especially if the effort of the farmer is also not observable and so a moral hazard problem exists. Moral hazard is not a problem in this situation if the quality of the good is perfectly observable as then the middleman can just pay the farmer a higher price when he successfully produces a high-quality good. However, if the quality of the good is not perfectly observable, in some cases the farmer may receive a high price even when he did not exert high effort and the good is of low quality. This means that if he is to exert effort, his incentive to produce high-quality goods must be increased by offering him a higher price for goods that appear to be of higher quality, thereby increasing the cost to the middleman. A middleman may also be unwilling to exert the necessary effort to maintain the quality of the good if he is not certain that it is of high quality. Vertical integration could overcome some of these problems.

This paper will present a model of a supply chain for a good involving two stages of production. Effort must be exerted at both stages if a high-quality good is to be produced. Effort is not observable and the quality of the good is not perfectly observable. The model predicts that there will be a range of values of the price difference between high-quality and low-quality goods for which production of high-quality goods will occur with vertical integration but will not occur if the tasks are carried out by separate agents. The range of price values for which this occurs will be decreasing as the level of observability of quality increases and will disappear as quality becomes perfectly observable. The paper will also present some case studies of supply chains for various products in a number of developing countries that have characteristics which are consistent with the predictions of the model.

Much of the existing literature related to quality focuses on the use of reputation to incentivise firms to produce goods of high quality. These papers describe models where consumers cannot immediately observe the quality of the good that they purchase but once they consume the good they learn the quality and they are able to punish firms who produce goods of lower quality than stated by refusing to buy from them in the future. Firms receive a price premium for producing high-quality goods.[1] Dana and Fong (2011) present a model which predicts that concern about loss of reputation can lead firms to produce higher-quality goods in oligopolistic markets but not monopolistic or competitive markets. Kranton (2003) argues that competition can eliminate the price premium for reputation needed to induce production of high quality. Esfahani (1989) argues that it is harder for reputation to sustain a high-quality equilibrium in developing countries because of the high rate of seller turnover, high idiosyncratic cost fluctuations and low entry costs.

Fafchamps, Vargas-Hill and Minten (2007) also suggest that reputation and repeated interaction cannot overcome the problem of poor quality in developing countries because producers are very far removed from consumers because of the large number of actors in the supply chain. They investigate the extent to which information about crop attributes is conveyed along the supply chain by examining evidence from supply chains for non-staple food crops in India. They find that while price premiums exist for observable product characteristics, no information is circulated about unobservable characteristics. As a result, growers have no incentive to invest in unobservable quality characteristics. This paper will abstract away from the question of reputation and focus on a situation where it is not possible for repeated purchases to act as an incentive for producing high-quality goods. It will demonstrate how, even in the absence of reputational concerns, vertical integration could lead to increased production of higher-quality goods.

A number of other papers have also discussed the issue of low-quality agricultural goods in developing countries. Robinson and Kolavalli (2010) describe the problems involved in maintaining quality in tomato markets in Ghana. They state that sales are based on quantity rather than quality. Quality can be difficult to assess as farmers often put poor-quality tomatoes on the bottom of the crate and better-quality tomatoes on the top. Middlemen exacerbate this problem by stacking crates on top of each other thereby further reducing the

[1] Shapiro (1983); Allen (1984); Riordan (1986); Gale and Rosenthal (1994).

quality of tomatoes at the bottom of the crate. Fafchamps and Gabre-Madhin discuss the problem of assessing quality in agricultural markets in Benin. They report that inspecting quality is challenging and time consuming and traders do not want to delegate this task to others. This increases their costs and limits their ability to expand their operations.

This paper adds to the literature by presenting a model where effort needs to be exerted at each stage in the production process in order to maintain quality. This set-up is similar in spirit to Kremer's O-Ring theory.[2] The model presented in this paper does not allow for heterogeneity in levels of skill, however. Instead, it investigates how the degree of observability of quality affects the decision of agents later in the chain about whether or not to exert effort.

The rest of this paper is organised as follows. Section 2 presents the theoretical model. Characteristics of a number of supply chains which are consistent with the predictions of the model are presented in Section 3 and Section 4 concludes.

2 Model

2.1 Description of economic environment

I will describe the supply chain of a good which involves two stages of production. I will use the example of a farmer and middleman in this paper but this model could apply to a number of other situations. There are two possible quality levels that the good can have, high or low, $Q \in \{H, L\}$. The final market price for a high-quality good is p^H and the price for a low-quality good is p^L. The quality of the good is perfectly observable to the final purchaser (e.g. a large processing company who has the technology to test for quality) but it is not perfectly observable at the intermediate production stage. A higher level of effort is required at both stages of the production process in order to produce a good of high quality. This effort is costly. The timing of the production process is as follows.

1. The decision is made about whether or not to exert high effort in the first stage of production. The cost of this effort is c^F. If high effort is exerted, the probability that the good that is produced will be of high quality is γ. If low effort is exerted, the good will be of low quality with certainty.

[2] Kremer (1993).

2. A signal, $s \in \{H, L\}$, regarding the quality of the good is received. $s = Q$ with probability ρ, $1 \geq \rho > \frac{1}{2}$. ρ gives us a measure of the observability of quality. If ρ is close to $\frac{1}{2}$, then it is very difficult to observe quality. If $\rho = 1$, then quality is perfectly observable.

3. The decision is made about whether or not to exert high effort in the second stage of production in order to maintain the quality of the good. The cost of this effort is c^M. If effort is exerted at this stage, the quality of the good will be preserved with certainty. If effort is not exerted, the quality of the good will be low.

4. The quality of the good is perfectly observed in the final stage and p^H will be received for the good if $Q = H$ and p^L will be received if $Q = L$.

The following sections will present the predictions of the model both for the case where each stage of production is carried out by a separate agent and for the vertically integrated case where one agent carries out both tasks.

2.2 Separate agents

Suppose there are two agents, a farmer and a middleman. Both agents are assumed to be risk neutral. The farmer carries out the first stage of production and the middleman carries out the second stage. The middleman cannot observe the farmer's effort level and cannot perfectly observe the quality of the good. His payment to the farmer can therefore only be based on the signal of quality that he receives. The middleman must decide whether or not to offer the farmer a contract such that the farmer has an incentive to exert effort.

2.2.1 Farmer's problem

Suppose the farmer receives h from the middleman if $s = H$ and l if $s = L$. If the farmer exerts high effort, his expected payoff will be:

$$\gamma\left(\rho h + (1-\rho)\, l\right) + (1-\gamma)\left((1-\rho)\, h + \rho l\right) - c^F$$

If he does not exert high effort, his expected payoff will be:

$$(1-\rho)\, h + \rho l$$

The farmer will therefore exert effort if

$$h - l \geq \frac{c^F}{(2\rho - 1)\gamma}$$

I will assume that a limited liability constraint applies so that $l \geq 0$. This assumption is important but not unreasonable. It means that we assume that the middleman cannot force the farmer to pay him if he receives a low signal. It is reasonable to assume that the worst that the middleman could do to the farmer would be to refuse to purchase the good. The farmer must also be willing to participate in the contract. I will assume that the value of the farmer's outside option is zero. The following condition must hold:

$$\gamma\left[\rho h + (1-\rho)\, l\right] + (1-\gamma)\left[(1-\rho)\, h + \rho l\right] - c^F \geq 0$$

Given the above constraints, from the point of view of the middleman, the optimal h and l which will induce the farmer to exert effort will be:

$$h^* = \frac{c^F}{(2\rho - 1)\gamma}$$

$$l^* = 0$$

2.2.2 Middleman's problem

The middleman has two decisions to make. He must decide whether or not to exert effort himself in the second stage and he must decide whether or not to induce the farmer to exert effort in the first stage. His decision about whether or not to induce the farmer to exert effort will depend on his own willingness to exert effort in the second stage.

Second Stage

The middleman will only exert effort in the second stage of production if he believes that effort was exerted in the first stage. If he has set $h \geq h^*$ in the first stage, then he will believe that the farmer exerted effort in the first stage with probability one. If he has set $h < h^*$ in the first stage, then he will believe that the farmer exerted effort in the first stage with probability zero.

In the second stage, a signal will be received about the quality of the good, which the middleman will use to form his beliefs about quality. If he believes

that no effort was exerted in the first stage then he will believe that the good is of low quality with probability one, regardless of the signal. If he believes that effort was exerted in the first stage, then his beliefs about the quality of the good will be formed as follows:

$$\mu^H = Prob(Q = H \mid s = H) = \frac{\gamma\rho}{\gamma\rho + (1-\gamma)(1-\rho)}$$

$$\mu^L = Prob(Q = H \mid s = L) = \frac{\gamma(1-\rho)}{\gamma(1-\rho) + (1-\gamma)\rho}$$

The middleman will then decide whether or not to exert effort. Once he is in the second stage, the costs from the first stage are sunk, so his decision will only depend on his belief about the quality of the good, the cost of effort required to preserve the quality of the good, and the difference between the price for a good of high quality and that for a good of low quality. Let $\widetilde{p} = p^H - p^L$.

If the following condition holds, the middleman will exert effort in the second stage when he receives a signal that the good is of high quality:

$$\widetilde{p} \geq c^M \left(\frac{\gamma\rho + (1-\gamma)(1-\rho)}{\gamma\rho} \right). \tag{1}$$

He will exert effort in the final stage when he receives a signal that the good is of low quality if the following condition holds:

$$\widetilde{p} \geq c^M \left(\frac{\gamma(1-\rho) + (1-\gamma)\rho}{\gamma(1-\rho)} \right). \tag{2}$$

The second condition is stronger so if the middleman is willing to exert effort when he receives a low signal, he will also be willing to exert effort when he receives a high signal.

First stage

Given that the middleman knows the choices that he will make in the second stage if effort is exerted by the farmer, he must use this to decide whether or not to induce the farmer to exert high effort in the first stage.

Proposition 1: *If* $c^M \left(\frac{\gamma(1-\rho)+(1-\gamma)\rho}{\gamma(1-\rho)} \right) \geq \widetilde{p} \geq c^M \left(\frac{\gamma\rho+(1-\gamma)(1-\rho)}{\gamma\rho} \right)$*, the middleman will induce the farmer to exert high effort if the following condition*

holds:

$$\widetilde{p} \geq \frac{\gamma\rho + (1-\gamma)(1-\rho)}{\gamma\rho}\left(\frac{c^F}{(2\rho-1)\gamma} + c^M\right) \tag{3}$$

Otherwise, only low-quality goods will be produced.

For these parameter values, the middleman is only willing to exert effort in the final stage if he receives a signal that the good is of high quality. Given this, the probability of successfully producing a good of high quality is $\gamma\rho$. He will only be willing to induce the farmer to exert high effort if his expected gain is greater than the expected cost that he will have to pay. The middleman will only pay h and c^M if a high signal is received.

Proposition 2: *If* $\widetilde{p} \geq c^M\left(\frac{\gamma(1-\rho)+(1-\gamma)\rho}{\gamma(1-\rho)}\right)$*, the middleman will induce the farmer to exert high effort if the following condition holds:*

$$\widetilde{p} \geq \frac{\gamma\rho + (1-\gamma)(1-\rho)}{\gamma}\left(\frac{c^F}{(2\rho-1)\gamma}\right) + \frac{c^M}{\gamma} \tag{4}$$

Otherwise, only low-quality goods will be produced.

In this case, $\widetilde{p}$ is large enough relative to c^M that the middleman will always be willing to exert effort in the second stage if effort has been exerted in the first stage, regardless of the value of the signal that he receives. Given this, the probability of producing a good of high quality is now γ. In this case, however, the middleman will always pay c^M.

The middleman's decision regarding the level of effort to exert will therefore depend on the relative parameter values. The possible effort levels that the middleman could choose are as follows:

1. Full effort: the middleman induces the farmer to exert high effort and always exerts effort himself.

2. Partial effort: the middleman induces the farmer to exert high effort and exerts effort himself when he receives a high signal.

3. No effort: the middleman does not induce the farmer to exert high effort and the farmer always produces low-quality goods.

Proposition 3: *Suppose* $\frac{c^M}{c^F} \geq \frac{\gamma\rho+(1-\gamma)(1-\rho)}{(2\rho-1)\gamma}\left(\frac{1-\rho}{(2\rho-1)(1-\gamma)}\right)$*. If* $\widetilde{p}$ *is such that Constraint 3 is not satisfied, no effort will be exerted. If* $\widetilde{p}$ *is such that*

Constraint 3 is satisfied but Constraint 2 is not satisfied, then partial effort will be exerted. If Constraint 2 is satisfied, then full effort will be exerted.

If $\frac{c^M}{c^F} \geq \frac{\gamma\rho+(1-\gamma)(1-\rho)}{(2\rho-1)\gamma}\left(\frac{1-\rho}{(2\rho-1)(1-\gamma)}\right)$, then c^M is relatively more important than c^F. This means that the middleman will be willing to induce the farmer to exert high effort at values of $\widetilde{p}$ which are lower than the value at which he himself would be willing to exert full effort. In this scenario,

$$c^M\left(\frac{\gamma(1-\rho)+(1-\gamma)\rho}{\gamma(1-\rho)}\right) > \frac{\gamma\rho+(1-\gamma)(1-\rho)}{\gamma}\left(\frac{c^F}{(2\rho-1)\gamma}\right)+\frac{c^M}{\gamma}$$

$$> \frac{\gamma\rho+(1-\gamma)(1-\rho)}{\gamma\rho}\left(\frac{c^F}{(2\rho-1)\gamma}+c^M\right) > c^M\left(\frac{\gamma\rho+(1-\gamma)(1-\rho)}{\gamma\rho}\right),$$

which means that Constraint 2 is the hardest constraint to satisfy. Once this has been satisfied, full effort will be exerted and the high quality good will be produced with probability γ.

Proposition 4: *Suppose* $\frac{c^M}{c^F} < \frac{\gamma\rho+(1-\gamma)(1-\rho)}{(2\rho-1)\gamma}\left(\frac{1-\rho}{(2\rho-1)(1-\gamma)}\right)$. *If Constraint 4 is not satisfied, no effort will be exerted. If Constraint 4 is satisfied, then full effort will be exerted.*

If $\frac{c^M}{c^F} < \frac{\gamma\rho+(1-\gamma)(1-\rho)}{(2\rho-1)\gamma}\left(\frac{1-\rho}{(2\rho-1)(1-\gamma)}\right)$, then c^F is relatively more important than c^M. The middleman would always be willing to incur c^M in the final stage (conditional on effort being exerted in the first stage) at values of $\widetilde{p}$ which are lower than the value at which he is willing to pay enough to induce the farmer to exert high effort. This means that Constraints 2 and 4 will be satisfied more easily than Constraint 3 and therefore partial effort will never be exerted in this case.

2.3 Vertically integrated firm

Now, suppose there is just one agent who carries out both tasks. As with the case with two agents, his decision about whether or not to exert effort in the first stage will depend on his willingness to exert effort in the second stage.

2.3.1 Second stage

The agent will know whether or not he exerted effort in the first stage. If he did not exert effort in the first stage then he will not exert effort in the second

stage as he knows that the good is of low quality. If he did exert effort in the first stage, then his decision to exert effort in the second stage will depend on his beliefs regarding the quality of the good. These beliefs will be formed based on the signal that he receives in the same way that the beliefs were formed by the middleman in the case with two agents. He will exert effort in the second stage when he receives a signal that the good is of high quality if Constraint 1 is satisfied and will exert effort when he receives a signal that the good is of low quality if Constraint 2 is satisfied.

2.3.2 First stage

The conditions that need to be satisfied in order for effort to be exerted in the first stage will be different from the case with two agents, as there will no longer be a moral hazard problem.

Proposition 5: *If* $c^M\left(\frac{\gamma(1-\rho)+(1-\gamma)\rho}{\gamma(1-\rho)}\right) \geq \widetilde{p} \geq c^M\left(\frac{\gamma\rho+(1-\gamma)(1-\rho)}{\gamma\rho}\right)$, *the agent will exert effort in the first stage if the following condition holds:*

$$\widetilde{p} \geq \frac{c^F}{\gamma\rho} + \left(\frac{\gamma\rho + (1-\gamma)(1-\rho)}{\gamma\rho}\right) c^M \tag{5}$$

Otherwise, only low-quality goods will be produced.

As in the case with two agents, for this value of $\widetilde{p}$, the agent is only willing to exert effort in the second stage if he receives a high signal. The probability of success will therefore be $\gamma\rho$. The cost that he has to pay for effort to be exerted in the first stage is now smaller, however, as he does not have to pay a premium to overcome the moral hazard problem.

Proposition 6: *If* $\widetilde{p} \geq c^M\left(\frac{\gamma(1-\rho)+(1-\gamma)\rho}{\gamma(1-\rho)}\right)$, *the agent will exert effort in the first stage if the following condition holds:*

$$\widetilde{p} \geq \frac{c^F + c^M}{\gamma} \tag{6}$$

Otherwise, only low-quality goods will be produced.

In this case, the agent is always willing to exert effort in the second stage if effort is exerted in the first stage. Therefore, it is as if there is just one task to be carried out and the cost is $c^F + c^M$. The probability of success will be γ.

The agent again must choose between three possible effort levels: full effort, partial effort and no effort.

Proposition 7: *Suppose* $\frac{c^M}{c^F} \geq \frac{1-\rho}{(2\rho-1)(1-\gamma)}$. *If* $\widetilde{p}$ *is such that Constraint 5 is not satisfied, no effort will be exerted. If* $\widetilde{p}$ *is such that Constraint 5 is satisfied but Constraint 2 is not satisfied, then partial effort will be exerted. If Constraint 2 is satisfied, then full effort will be exerted.*

This situation is comparable to that in Proposition 3. The condition on the parameter values is different, however. As $\frac{\gamma\rho+(1-\gamma)(1-\rho)}{(2\rho-1)\gamma}\left(\frac{1-\rho}{(2\rho-1)(1-\gamma)}\right) > \frac{1-\rho}{(2\rho-1)(1-\gamma)}$, this situation will apply for a lower value of $\frac{c^M}{c^F}$ than in the case with two agents. This is because the actual cost of making sure that effort is exerted in the first stage is greater in the case with two agents.

Proposition 8: *Suppose* $\frac{c^M}{c^F} < \frac{1-\rho}{(2\rho-1)(1-\gamma)}$. *If* $\widetilde{p}$ *is such that Constraint 6 is not satisfied, then no effort will be exerted. If* $\widetilde{p}$ *is such that Constraint 6 is satisfied then full effort will be exerted.*

In this situation, c^F is relatively more important and so either no effort will be exerted or full effort will be exerted. This is comparable to Proposition 4 in the two agent case but again the constraint necessary for high-quality production to take place is easier to satisfy in this case.

2.4 Comparison of two agent case with vertical integration

2.4.1 Case 1: $\frac{c^M}{c^F} \geq \frac{\gamma\rho+(1-\gamma)(1-\rho)}{(2\rho-1)\gamma}\left(\frac{1-\rho}{(2\rho-1)(1-\gamma)}\right) > \frac{1-\rho}{(2\rho-1)(1-\gamma)}$

For low values of $\widetilde{p}$, no effort will be exerted with or without integration. As $\widetilde{p}$ increases, we will hit the partial effort constraint. This happens for lower values of $\widetilde{p}$ in the integrated case than in the two-agent case, as

$$\frac{\gamma\rho+(1-\gamma)(1-\rho)}{\gamma\rho}\left(\frac{c^F}{(2\rho-1)\gamma}+c^M\right) \geq \frac{c^F}{\gamma\rho}+\left(\frac{\gamma\rho+(1-\gamma)(1-\rho)}{\gamma\rho}\right)c^M$$

If $\widetilde{p}$ lies between these values, high-quality goods will not be produced in the two-agent case but will be produced in the integrated case. From now on I will refer to this range of value of $\widetilde{p}$ as the 'production gap'. Once $\widetilde{p}$ becomes greater than $c^M\left(\frac{\gamma(1-\rho)+(1-\gamma)\rho}{\gamma(1-\rho)}\right)$, full effort will be exerted regardless of the structure of the supply chain.

2.4.2 Case 2: $\frac{\gamma\rho+(1-\gamma)(1-\rho)}{(2\rho-1)\gamma}\left(\frac{1-\rho}{(2\rho-1)(1-\gamma)}\right) > \frac{c^M}{c^F} \geq \frac{1-\rho}{(2\rho-1)(1-\gamma)}$

For these parameter values, the agent will be willing to exert partial effort for some values of the price in the integrated case but not in the two-agent case. If the following is true

$$c^M\left(\frac{\gamma\left(1-\rho\right)+\left(1-\gamma\right)\rho}{\gamma\left(1-\rho\right)}\right) > \widetilde{p} \geq \frac{c^F}{\gamma\rho}+\left(\frac{\gamma\rho+\left(1-\gamma\right)\left(1-\rho\right)}{\gamma\rho}\right)c^M$$

partial effort will be exerted in the integrated case but no effort will be exerted in the two-agent case. As $\widetilde{p}$ increases, we will reach the following situation:

$$\frac{\gamma\rho+\left(1-\gamma\right)\left(1-\rho\right)}{\gamma}\left(\frac{c^F}{\left(2\rho-1\right)\gamma}\right)+\frac{c^M}{\gamma} > \widetilde{p} \geq c^M\left(\frac{\gamma\left(1-\rho\right)+\left(1-\gamma\right)\rho}{\gamma\left(1-\rho\right)}\right)$$

where full effort will be exerted in the integrated case but still no effort will be exerted in the two-agent case. Once $\widetilde{p}$ becomes large enough that it is greater than $\frac{\gamma\rho+(1-\gamma)(1-\rho)}{\gamma}\left(\frac{c^F}{(2\rho-1)\gamma}\right)+\frac{c^M}{\gamma}$, full effort will be exerted in the two-agent case.

2.4.3 Case 3: $\frac{\gamma\rho+(1-\gamma)(1-\rho)}{(2\rho-1)\gamma}\left(\frac{1-\rho}{(2\rho-1)(1-\gamma)}\right) > \frac{1-\rho}{(2\rho-1)(1-\gamma)} \geq \frac{c^M}{c^F}$

For these parameter values, partial effort is never exerted so we only need to compare the conditions for full effort to be exerted. As before, this condition will be satisfied for lower values of $\widetilde{p}$ in the integrated case than in the two-agent case, as

$$\frac{\gamma\rho+\left(1-\gamma\right)\left(1-\rho\right)}{\gamma}\left(\frac{c^F}{\left(2\rho-1\right)\gamma}\right)+\frac{c^M}{\gamma} \geq \frac{c^F+c^M}{\gamma}$$

If $\widetilde{p}$ lies between these values then high-quality goods will be produced in the integrated case but not in the two-agent case.

2.5 Comparative Statics

2.5.1 Degree of observability, ρ

As ρ increases, the range of values of $\widetilde{p}$ over which it is profitable to produce at all increases. However, as the price that the middleman must pay to the farmer in the two-agent case is decreasing in ρ, this range of values increases faster in the two-agent case than in the integrated case and therefore the production gap becomes smaller.

For a given $\frac{c^M}{c^F}$, if ρ is small we will be in Case 3 above where only full effort or no effort will be exerted. The production gap will be equal to:

$$\frac{1-\rho}{\gamma^2(2\rho-1)}c^F$$

which is decreasing in ρ. As ρ continues to increase, we will move to Case 2, where partial effort will be exerted for some values of $\widetilde{p}$. In this case the production gap will be equal to

$$\left[\frac{\rho(\gamma\rho+(1-\gamma)(1-\rho))-\gamma(2\rho-1)}{\gamma^2\rho(2\rho-1)}\right]c^F+\frac{(2\rho-1)(1-\gamma)}{\gamma\rho}c^M$$

Since in this case $\frac{c^M}{c^F}<\frac{1-\rho}{(2\rho-1)(1-\gamma)}$, this gap will be smaller than when we were in Case 3 and will still be decreasing in ρ. Eventually we will move to Case 1, where the production gap will be equal to:

$$\frac{1-\rho}{\gamma^2\rho(2\rho-1)}c^F$$

Again, given the value of ρ in this case, this gap will be smaller than in the previous case and will continue to decrease as ρ increases. If $\rho=1$, the difference will disappear and there will be no loss in efficiency from not having an integrated supply chain.

2.5.2 The middleman's cost, c^M

For a given ρ and c^F, if c^M is sufficiently high we will be in Case 1 above. As long as we remain in this case, the production gap will remain constant as c^M falls. However, eventually c^M will become small enough that we will move to Case 2, where for this range of parameter values, the gap will be smaller than it was in Case 1. Also, the gap will now depend on c^M and will continue to fall as c^M falls. Finally, if c^M continues to fall, we will move to Case 3. Once again, in this case the size of the gap will be smaller than in the previous cases. It will no longer depend on c^M, however, so it will remain constant from now on as c^M falls.

2.5.3 The farmer's cost, c^F

As with c^M and ρ, as c^F falls, the production gap falls. For a given c^M and ρ, if c^F is high, we will be in Case 3. As c^F falls we will move from Case 3 to Case

2 and eventually to Case 1. In each successive case, the production gap will be smaller and within each of these cases it will be decreasing in c^F. As c^F goes to zero, the production gap will also go to zero.

2.6 Summary of findings

The decision to produce high-quality goods will depend on the costs of production, the degree of observability of quality and the price difference between goods of high and low quality. If quality is not perfectly observable, it is more costly to the middleman to overcome the problem of the farmer's moral hazard. He will therefore need a larger price difference between high- and low-quality goods in order to convince him to induce effort in the farmer and exert effort himself. The lack of observability of quality increases the cost of production of high-quality goods in the first stage when the two stages are carried out by different agents but not in the vertically integrated case. This creates a 'production gap' as there is a range of values of the price difference between high- and low-quality goods for which high-quality goods are produced in the vertically integrated case but not in the case with two agents. In addition to increasing the first-stage cost of producing high-quality goods, a lower ρ also decreases the likelihood that partial effort will be exerted as this will only happen when the expected cost paid to the farmer is low relative to c^M. This also increases the production gap.

3 Empirical Observations

This section will discuss the structure of supply chains for a number of different products. It will present two examples of products where the degree of observability of quality is low: milk and cocoa. It will also present two examples of products with a higher degree of observable quality: chilli and rice. In the case of the first two products, we will see that high-quality goods are only produced in situations where the supply chain is short. However, in the second two cases, we will see that it is possible to produce higher-quality products even when there is a high degree of intermediation in the supply chain.

3.1 Milk

There is a significant difference between the structure of dairy supply chains in developed countries and those in a number of developing countries. In developed countries, the supply chain for dairy tends to be very short. Most milk is produced through cooperatives who deliver the milk directly to a processor. Farmer who do not sell their milk through cooperatives sell directly to processors themselves. The milk that is produced is rigorously tested and of high quality.[3] In the case of the developing countries discussed in this section, the situation is quite different. The supply chain for milk in these countries involves many actors and is plagued by problems of low quality. The vast majority of milk that is sold is raw, unprocessed milk which must be boiled before use and is often adulterated with water.[4] A report by TechnoServe Rwanda (2008) estimates that 96% of milk marketed in Rwanda is through the informal channel even though the price of processed milk is 2-2.5 times that of fresh raw milk. A similar situation can be found in Pakistan:

> Dairying in Pakistan is labour-intensive and engages a large number of agents along the value chain, including 6.8 million farmers, and thousands of milk collectors, transporters, processors, distributors and retailers. ... In the absence of checks and balances, adulteration is rampant, as each agent in the marketing chain seeks to maximize profits. (Zia, Mahmood and Ali, 2011; p. 10-11)

Much of the adulteration is attributed to intermediaries in the chain who try to keep the milk cool during transport by adding ice or who add washing powder and maize flour to try and enhance volume and whiteness. Adulteration by farmers is also common as they try to increase the volume by adding water since milk tends to be bought on the basis of quantity rather than quality.[5]

Observing the quality of milk can be very challenging. A basic level of quality in milk can be observed by sight, smell and taste but testing for most of the characteristics of high-quality milk, such as the presence of bacteria and fat content, involves more sophisticated equipment and cannot be carried out by local middlemen.[6]

According to a report by the SNV Netherlands Development Organisation (2008):

[3] Smith and Thanassoulis (2008) and DairyCo (2011).
[4] Faye and Loiseau (2002) and SNV Netherlands Development Organisation (2008).
[5] Zia, Mahmood and Ali (2011).
[6] Kibiego (2010).

> The present system in Ethiopia for testing of raw milk and dairy products (with the exception of some research testing laboratories like ILRI) does not stimulate the production of good quality, biologically pure milk with high technological quality that meets the national/ international standards. Currently there are no proper means for collecting and processing of information concerning the milk and milk products quality for marketing. (p. v)

In terms of the model presented in the previous section, this would correspond to a very low value of ρ. In addition to the low level of observability of quality, it is costly for middlemen to try and preserve the quality of milk during transportation as the handling and storage of the milk must be carried out with care in order to prevent contamination. The milk can be contaminated by storage material that has not been properly disinfected or by transporting the milk for too long without proper cooling equipment.[7] Rota and Sperandini (2010) report that transportation and handling costs make up the largest portion of marketing costs of fresh milk. The combination of high costs to the middleman and low observability of quality means that middlemen have little incentive to pay farmers a higher price in order to encourage them to produce higher-quality milk.

This is not to suggest that no high-quality milk is produced in these countries. In general, however, the value chain for high-quality milk is much shorter and looks more like the supply chains for dairy that we see in developed countries. In Pakistan, there are a number of formal processors who produce processed, fresh milk. They usually buy milk directly from farmers rather than through middlemen and they provide the transport themselves using refrigerated tanks. They have also set up farm cooling tanks in the villages where they collect the milk.[8]

In Ethiopia, the Adaa Dairy Cooperative which has 813 members has managed to start producing higher-quality milk which is then delivered directly to one of 12 collection points where the milk is tested for quality.[9] TechnoServe Rwanda (2008) reports a similar situation in Rwanda where a number of farmers in the region around Kigali are vertically integrated into the dairy market and many of the owners of dairy farms also own a processor or retailer.

Finally, much of the production of high-quality milk in developing countries

[7] Faye and Loiseau (2002) and SNV Netherlands Development Organisation (2008).
[8] Zia, Mahmood and Ali (2011).
[9] SNV Netherlands Development Organisation (2008).

is supported by large multi-national corporations, such as Nestlé, who work directly with farmers to source the milk and provide the necessary infrastructure for safely transporting the milk without it being contaminated. In addition, these companies provide training to farmers to help them improve their production techniques so that they can produce high-quality milk.[10]

3.2 Cocoa

This section will compare the structure of the supply chain for cocoa in two major cocoa producing countries: Indonesia and Ghana. The quality of cocoa produced in Indonesia is generally quite poor. In contrast, Ghana has a reputation for producing high-quality cocoa. The supply chains for cocoa in these two countries have quite different structures. There are many actors involved in the supply chain for cocoa in Indonesia. Farmers generally sell to local collectors at the farm gate who then sell on to village collectors who sell to processors or other intermediaries.

The supply chain in Ghana is much shorter. The cocoa industry in Ghana is strictly regulated by the Cocoa Marketing Board, Cocobod. Farmers either sell directly to Licensed Buying Companies (LBCs) or to farmers' associations, both of whom sell directly to Cocobod.

Observing the quality of cocoa beans is not quite as difficult as in the case of milk but it still poses a number of challenges. In order to meet international standards, high-quality cocoa beans should possess the following characteristics:

> Cocoa beans of good quality are free from insect holes, smoky and flat beans. They are not excessively acidic, bitter or astringent, and they have uniform sizes. They should also be well fermented, have a moisture content of maximum 7.5 %, a free fatty acid content maximum 1.5 % and a cocoa butter content between 45 and 60 %. Finally, too high levels of foreign matters, insects, harmful bacteria and pesticides residues are not allowed ... International standards are made to measure quality of cocoa beans. This is performed via a cut test where the cocoa beans are cut lengthwise and visually divided after quality. Purple beans, slaty beans and beans with all other defectiveness are grouped. Defectiveness among cocoa beans includes flat, moldy and germinated beans" (Mikkelsen, 2010; p.19)

[10] Zia, Mahmood and Ali (2011) and http://www.nestle.com/Brands/Dairy/Pages/DairyCSV.aspx

Mikkelsen (2010) outlines the steps involved in identifying and handling high-quality beans. Many of the problems with the cocoa beans can be detected by sight via a cut test. However, to ensure that the batch of cocoa beans is generally of good quality, this must be carried out with a significant sample of the beans which is time-consuming. In addition, specialised equipment is necessary to measure the moisture content of the beans and a sample of the beans must be weighed and counted in order to determine bean size.

If the middleman is willing to buy high-quality beans, then he must exert effort in order to maintain the quality of the beans. High-quality cocoa beans must be stored with care in order to preserve quality. Sacks must be secure and tight to protect from insect infestation. They also need to be kept dry and protected from high temperatures.[11] Most importantly, they should not be mixed with beans of lower quality.

Cocoa beans in Indonesia are generally purchased on the basis of quantity rather than quality. Collectors do not differentiate on the basis of quality in terms of the price that they pay the farmer. In addition, they mix beans of different quality with each other and sometimes also with waste material in an effort to increase volume:[12]

> The common practice has been for the first buyer (local collector) to pay the same price per kilogram for both good and poor quality cocoa, 'mixing' the beans and forwarding these mixed beans on to the next buyer (village collector). When the cocoa beans eventually arrive at the warehouse of the international exporter they then need to be cleaned or 'unmixed' to meet the international buyer's specifications. (Badcock, Matlick, and Bako Baon, 2007; p. 3).

There are a number of actions that farmers can take in order to produce high-quality cocoa beans. A major cause of low quality in cocoa beans is infestation by the cocoa pod borer. The farmer could exert effort to protect his crops from infestation. He could also improve the quality of his beans by fermenting them. However, these actions are costly for the farmer and he has no incentive to carry them out as the collector is not willing to pay a higher price for beans that appear to be of higher quality.

In general, there is little cooperation between cocoa farmers in Indonesia and associations or cooperatives do not exist. A few local processors have begun

[11] Mikkelsen (2010).
[12] Panlibuton, Henry, and Lusby (2006).

to set up 'up-country' buying stations in order to try and source high-quality beans directly from farmers.[13] A number of international organisations have also started to work directly with farmers in order to increase the level of quality in the beans that they purchase. Armajaro and Olam have both established buying stations that are located close to farmers where quality control is carried out and farmers are paid a premium for high-quality beans.[14]

Cocoa production in Ghana follows a very different model which is focused on producing high-quality cocoa beans. The cocoa marketing board in Ghana (Cocobod) plays a major role in ensuring that the quality of cocoa is high. Farmers either sell cocoa to Licensed Buying Companies (LBCs) or farmer associations.[15] Cocoa is strictly graded and checked for quality at a number of stages in the chain. Low-quality cocoa is rejected by Cocobod providing a strong incentive to the LBCs to perform quality checks at an early stage in the supply chain:

> Because cocoa is graded early in the marketing chain and identified by farming society, farmers are motivated to present high quality cocoa and are also instantly aware (and penalised, by not being able to sell their cocoa) when their cocoa is sub standard (Shepherd and Onumah 1997: 46; Bank of Ghana 2003: 10). By contrast, in other cocoa producing countries cocoa is generally graded much later in the chain and not always traced back to its origin, giving farmers little information about their cocoa's quality and few incentives to improve it. (Williams, 2009; p. 25)

As was the case with the dairy supply chain we only see high-quality goods being produced when the supply chain is highly integrated.

3.3 Chillies

This section will discuss the supply chain for chilli in Indonesia. As was the case for cocoa, the supply chain for chilli involves a number of different actors: local collectors, wholesalers, retailers, supermarkets. However, in the case of chilli, quality is much more easily observable. Most of the characteristics of chilli that differentiate quality can be judged by sight such as size, shape and colour.

[13] Panlibuton, Henry, and Lusby (2006).
[14] Badcock, Matlick, and Bako Baon (2007) and VECO (2011).
[15] Mohammed, Asamoah, and Asiedu-Appiah (2012).

In South Sulawesi in Eastern Indonesia, two main types of chilli are produced: large chilli and small chilli. Large chilli is considered to be of higher quality and sells for a higher price. However, the production of large chilli is also more costly. Different inputs and techniques are used:

> In South Sulawesi there are a number of key differences between small chilli and Large chilli producers: Small chilli producers do not use high quality certified seed, whereas farmers in the same province producing Large chilli are using certified seed. The use of certified seed is used due to stronger market demand and greater intensity of cultivation. Small chilli cultivation appears to be less intensive and uses less chemical inputs compared to large chilli farming. (White, Morey, Natawidjaja, and Morgan, 2007; p.26)

Collectors and wholesalers must also exert some effort to sell high-quality chilli to supermarkets such as sorting, grading and packaging the chilli.

Even though the supply chain for large chilli is quite long, there is a market for it. Large chilli is produced and farmers receive a higher price for producing it. In 2005, 62% of chilli production was large chilli and 38% was small chilli.[16] The most common form of supply chain for chilli in Indonesia is for farmers to sell to local collectors who then sell to wholesalers or retailers. The wholesalers may sell to small retailers or to supermarkets. Collectors pay a higher price for higher-quality chilli.

An exception to the long supply chain is the case of chillies produced to make chilli sauce. ABC is a processor of chilli sauce in Indonesia and buys at least half of its chilli directly from growers. The company needs the farmers to grow a particular variety of chilli in order for it to have the right flavour, which is a characteristic that is more difficult to observe than the size of the chilli.

3.4 Rice

The final product that will be discussed is rice. This section will describe the production of rice in Vietnam and Thailand. In both of these countries many actors are involved in the supply chain for rice: producers, assemblers, middlemen/brokers, wholesalers, millers/polishers and retailers. Similarly to the case of chilli, the quality characteristics of rice are easily observable:

[16] White, Morey, Natawidjaja, and Morgan (2007).

> In general, there is a broad range of rice qualities available in the market place in the Mekong River Delta, Vietnam. The difference in the qualities are based on the rice variety, the way of milling the rice influences to what extent the grains are broken (broken level), the period the rice has been in storage, and the purity of the rice. (Hai, 2002; P.82)

Most rice traders in Vietnam differentiate rice into two types, long and medium/ short. Long-grain rice is higher quality and the growers receive a higher price. Of paddy sold at the farm gate in the Mekong Delta, approximately 60% is long grain paddy and 40% is short grain. In Thailand, two types of rice are also produced: glutinous and non-glutinous. Non-glutinous rice is of higher quality and growers receive a higher price from traders for this type of rice but must also use more intensive technology in order to produce it.[17] Glutinous rice is grown for own consumption or sold locally and non-glutinous rice is grown commercially.

We can see that in the case of chilli and rice, where quality characteristics are easily observable, high-quality products are produced even where there are many agents participating in the supply chain.

4 Conclusion

This paper presented a model of a supply chain which demonstrated that the decision to produce low-quality goods can be explained by a combination of low observability of quality and a high level of intermediation in the supply chain. The model predicts that if the quality of the good is not perfectly observable, then a 'production gap' will exist. This means that there will be a range of values for the price difference between high- and low-quality goods for which high-quality goods will be produced if the supply chain is vertically integrated but will not be produced if the different tasks are performed by separate agents. The paper also discussed examples of supply chains in a number of developing countries that have characteristics which are consistent with the predictions of the model.

The model predicts that the size of the production gap will be decreasing in the degree of observability of quality and increasing in the cost to the farmer

[17] Agrifood Consulting International (2005).

of producing a high-quality good and the cost to the middleman of preserving the quality of the good. This means that, from a policy perspective, there are a number of ways in which the production of high-quality goods could be encouraged. Firstly, the government could support the formation of farmers' associations which could perform some of the tasks of the middleman by transporting the goods to the processor. Secondly, processors could be encouraged to establish operations 'up country' in order to buy directly from farmers and test for quality earlier in the supply chain. Thirdly, the costs to farmers could be reduced by training them to use more efficient production techniques or, once again, by encouraging farmers to work together in a cooperative in order to reduce costs. Finally, investing in better roads could reduce the middleman's costs and the cost to the farmer of sourcing inputs.

The analysis in this paper has taken the degree of integration of the supply chain as exogenous in order to better understand one side of the problem. In reality, the decision of whether or not to vertically integrate may be endogenous. Incorporating this into the model could be an important avenue for future research.

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