Essays in Development Economics

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To my mother, uncle Javaid Iqbal, and aunt Parveen Iqbal.

Abstract

This dissertation consists of three essays in development economics. The first essay is concerned with competition between two processing mills in the sugarcane market of Pakistan. I develop a two-stage duopsony game where, in the first period, mills fragmentize the market by investing in the procurement logistics and infrastructure to create captive segments in the market. In the second stage, mills take the segmentation given and compete in prices. The model endogenously determines the market fragmentation. In equilibrium, complete segmentation of the market emerges, mills buy cane from mutually exclusive segments of the market. Finally, I show that a binding price floor has no effect on the market segmentation. The second essay is concerned with coordination amongst processing mills. I analyse why sugar mills in Pakistan pay cane farmers by weight instead of sucrose content? I develop a two-stage pricing game. In the first stage, mills choose the price regime: pay by weight or sucrose content. In the second stage, for a given price regime, mills compete in prices. The model suggests that evaporation of moisture increases the effective transportation cost for farmers and hence reduces the competition between mills. Numerical solution to the game generates a coordination game. The fact that mills pay by weight, payoff dominant equilibrium, indicates a collusive behaviour among mills. However, I could not rule out the possibility of historical inertia when parameter values represent the historical conditions of the market. Finally, I suggest a price floor as an equilibrium switching policy. The final essay of this dissertation is concerned with cooperation between rural households. I study informal risk sharing contracts when players' behaviour is motivated not only by their material payoff but also by intrinsic motivations. My results suggest that emotions such as envy, altruism, and intentions work in different directions. Envy and altruism not only reduce the critical discount factor that can self-sustain risk sharing but also make the sharing mechanism more equitable by reducing the number of equilibria in the repeated game. Finally, I study intention based preferences in an infinity repeated psychological game. The main result of the final chapter shows that intrinsic reciprocity based on expectations and intentions can reduce the level of informal insurance by increasing the critical discount factor.

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Chapter I

Introduction

In this thesis, I study competition, coordination, and cooperation amongst mills, farmers and rural households in developing countries. The first two essays are concerned with the competition and coordination between processing mills in the sugarcane market of Pakistan. The aim of this research is to understand the strategic behaviour of mills. This market is of particular interest to me because of its peculiar nature. Cane farms are often small in size and sell their crop to processing mills that enjoy monopsony power. The perishable nature of the cane, high transportation costs, and underdeveloped infrastructure limit farmers' access to local mills. Mills make investments that facilitate farmers' delivery. These investments also restrict farmers from accessing other mills in the neighbouring area and fragment the market into captive segments. The pricing structure of the market is paradoxical in the sense that mills prefer paying by the weight of the cane and not by the quality of the cane, despite the fact that better quality increases the recovery rate of sugar.

In the second chapter, I study processing mills' market segmentation strategies. I develop a two-stage duopsony game where in the first period, mills fragment the market by investing in the procurement procedure and infrastructure to create captive segments in the market. Farmers located in this segment can only sell to the investing mill. This endogenously determines the fragmentation in the markets. In the second stage, mills take the segmentation given and compete in prices. In equilibrium, complete segmentation of the market emerges, mills buy cane from mutually exclusive segments of the market and pay farmers the monopsony price. I show that if the marginal cost of investment goes to zero, then the market is equally divided between mills. Finally, I show that introducing a price floor reduces mills' profits but does not affect the segmentation of the market.

In the third chapter, I study the following question: why do sugar mills in Pakistan pay cane farmers by weight instead of sucrose content? I develop a two-stage duopsony pricing game. In the first stage, mills choose the price regime: payment by weight or by sucrose content. In the second stage, for a given pricing regime, mills compete in prices. I show that if both mills choose the same regime, then the equilibrium profits are higher under the weight regime. The intuition behind this result is as follows. The cane starts losing its moisture and weight immediately after the harvest. Mills' revenue from one unit of cane remains the same under both regimes, but the per unit cost of purchasing cane is lower under the weight regime. The model suggests that evaporation of moisture increases the effective transportation cost for farmers and hence reduces the competition between mills. This reduction in the competition increases mills' profits under weight pricing. Numerical analysis generates a coordination game where two pure strategy equilibria emerge: both mills pay by weight and both pay by sucrose content in the second stage of the game. Paying by weight is payoff dominant equilibrium, and sucrose pricing is risk dominant. The fact that mills pay by weight indicates collusive behaviour among mills. I also show that under the parameter values that represent the historical conditions of the market, weight pricing is the only equilibrium; indicating the possibility of historical inertia. Finally, I suggest a price floor as an equilibrium switching policy. The policy need not be permanent, once sucrose pricing is attained, the new price regime is self-enforcing.

The final chapter of this dissertation is concerned with cooperation amongst rural households. In particular, I study bilateral informal risk sharing mechanisms. Economists have traditionally relied on rational self-interest to explain informal risk sharing arrangements. However, experimental evidence suggests that emotions can also help enforce contracts. In this chapter, I study informal risk sharing contracts when players' behaviour is motivated not only by their material payoff but also by intrinsic motivations. My findings suggest that emotions such as envy, altruism, and intentions work in different directions. By using Fehr-Schmidt preferences, I show that envy and altruism not only reduce the discount factor that is necessary to support risk sharing but also make the sharing mechanism more equitable by reducing the set of feasible and individually rational payoffs in the repeated game. To model intentions, I then use a psychological game theory framework that accounts for preferences for reciprocity. These belief-based preferences are then nested into an infinitely repeated game that captures traditional economic incentives. My results show that intrinsic reciprocity based on expectations and intentions can reduce the level of informal insurance by increasing the critical discount factor.

Chapter II

Strategic Fragmentation of Sugarcane Market and the Effect of Price Floor

1 Introduction

Agricultural markets are generally characterized by a large number of producers of raw goods, who are spatially dispersed and act as price takers. Their products are mostly perishable and bulky, hence costly to transport from farms to processing mills. While the market for the finished product of processing mills is national or international, raw products have a very localized market. This limits farmers' access to mills within neighboring areas, giving farmers limited outside options. Institutional structure, infrastructural needs and procurement logistics require that mills make certain investments in the market to coordinate better between farmers and mills. However, mills may use these investments strategically to segment the market. As a result, processing mills can exercise market power over farmers. These problems are acute in developing countries where the infrastructure and institutional setup in rural areas are not well developed. Market power can have severe implications on the income of farmers as well as on choices of crops to grow. To protect farmers from exploitation, governments in the developing countries often intervene by setting a price floor.

In this chapter, I study competition between sugar processing mills in Pakistan. Pricing and procurement behaviour of the processing mills suggest that mills often buy cane from entirely exclusive segments of the market despite the fact that some parts of the market could be served by other mills (SDPI, 2012). In this chapter, I argue that the investments made by mills to facilitate farmers to deliver cane to mills can be used strategically to segmentize the market and allow mills to charge monopsony prices.

There are three key players in the Pakistani sugarcane market: processing mills, farmers, and the government. Their interaction creates an interesting market structure that I describe now. Farmers grow cane on their land and sell it to the processing mills in the surrounding area. Mills buy cane from farmers and process it to produce sugar. Both farmers and mills are free to choose their trading partners.

However, the market structure can best be described as oligopsonistic. Mills enjoy monopsony power over farmers for a number of reasons. Poor infrastructure and perishable nature of cane limit farmers' reach to mills[1]. Historically, mills have played a key role in developing infrastructure in rural areas by investing in the road network. Mills have invested in the local road infrastructure that connects farmers to highways and often use political influence to create a better highway network in rural areas. Since sugarcane is an extremely bulky crop, transportation costs are high. Cane is transported by tractor and trolleys, and to save on transportation costs farmer tend to overload these trolleys. Considering the poor road quality in rural areas, trolleys frequently overturn and block the roads, causing losses to farmers. Overturned trolleys also result in delays for other farmers as it often requires at least a day to clear the road. Farmers then prefer supplying cane to mills in the neighbouring area. To cope with these problems and to facilitate farmers' delivery of cane to mills, mills set up weighing scales and delivery points in villages. Instead of delivering cane to mills' gate, farmers sell the crop at these weighing and collection stations. The cane is then transported to the mill at the mill's own expense. Finally, mills procure sugarcane village by village. A mill decides on a time window during which it will purchase cane from a particular village and advertise this fact through its agent in the field. Given the perishability of cane and the risks involved in transporting the cane, a farmer does not normally switch to another mill unless the farmer is sure that his village fits in the mill's schedule. If however a farmer deviates from rest of the village (selling cane to a mill different from rest of the village), then his crop has to be accommodated in mill's crushing schedule. This buying procedure makes it difficult for farmers to switch to other mills. Mills can, but often do not, compete over the same farmland for cane.

Once the linkages and relationships are established, the marginal cost of procuring cane goes down significantly, and mills can benefit for a long period of time. According to Naseer (2007) in the years $2002-03$ and $2003-04$ only 10% and 7% of farmers switched mills in Faisalabad and Badin districts. Both of these districts have one of the highest number of mills, 7 in each. Therefore, even in the most competitive environment, farmers switch mills infrequently.

From the above discussion, it is clear that mills enjoy substantial monopsony over farmers. However, the sugarcane market may not be considered as a set of monopsony islands because while some farmers have access to only one mill, others can easily reach two or more mills. Mills can make investments in poaching farmers from rival's captive segments, especially when most of the mills are producing

[1]Chapter 3 gives a detailed description of the post-harvest deterioration of cane.

only $50-60\%$ of their output capacity. Therefore, a prototype location model that assumes that mills can compete over the entire market may not be appropriate for studying such markets. To analyse mills' behaviour in the market, I develop a simple two-stage duopsony game where in the first period processing mills simultaneously make the costly investment to fragment the market by capturing a segment of farmers in the market. Farmers who have been segmented by mills can only sell their cane to the investing mills, following Basu and Bell (1991), I call them a captive segment. However, it is possible that a segment of the market is targeted by both mills, and farmers in this segment may sell their crop to any mill which pays the higher price. This segment of the market is called the contested segment. The market may remain entirely segmented, without any contested segment, if mills do not invest in creating a contested segment, leading to pure monopsonies. At the other extreme, both mills may target the entire market and create the Bertrand-type competition for duopsony. I assume that both mills can target any farmer in the market by establishing collection points anywhere in the farmland. In the second stage, mills take the market fragmentation given and compete in prices.

A similar problem was studied in a seminal paper by Basu and Bell (1991). They modelled a two stage game where the market is fragmented by competing landlords who employ peasant farmers in the first stage. In the second stage, the same farmers become captive borrowers for the landlords. On the other hand, there is a large literature that studies exogenously segmented markets. Notably, Narasimhan (1988), Varian (1980) and Deneckere et al. (1992) consider a similar price competition when consumers are exogenously tied to a certain brand. More recently, there has been a growing literature, mainly related to advertising, which endogenizes the segmentation, among many others, see Fudenberg and Villas-Boas (2005), Galeottia and Moraga-Gonzálezb (2008), Fundenberg and Tirole (2000) and Bagwell (2007) for an extensive survey. I, however, develop a simple two-stage duopsony game that captures price competition and a strategic investment decision to segment the market. My results show that in equilibrium the entire farmland is shared by mills as exclusive captive segments where only a single mill buys cane from each farmer. Thus, investments made by mills to facilitate the farmers actually decrease competition and increase the monopsony power of mills. I show that there is a set of equilibrium outcomes centred around equal shares. However, the set of equilibria shrinks when the marginal cost of targeting farmers goes down. When the marginal cost approaches zero, each mill acts as a monopsony over half of the market. The intuition behind this result is as follows: if the cost of targeting farmers is relatively low and the rival mill captures a bigger segment of the market, then a mill finds it optimal to invest and poach on the rival's suppliers and compete fiercely in prices. If however, the marginal cost of poaching a farmer is high, then mills may find it opitmal to accommodate relatively unequal segmentation of the market. Finally, I show that the imposition of price floor does not affect the segmentation in the market, it however reduces mills' profits.

The rest of the chapter is structured as follows. Section 2 sets up the model. Section 3 and 4 analyse price and investment competition in the first and second period of the game respectively. Section 5 analyses the effect of the price floor on mills' investment behaviour. Finally, Section 6 concludes.

2 The Model

I develop a two-period game with two identical sugar processing mills, 1 and 2. We refer to these mills as i and j. Each mill is located at one end of the interval. Mill 1 is located at 0 and mill 2 is located at 1. Mills buy sugarcane from identical farmers. Farmers are located uniformly on the unit interval $[0, 1]$ and total mass farmers is normalized to 1. Each farmer produces one unit of cane and values it equal to ω and $\omega > 0$[2]. The value of each unit of cane to the mill is R and each mill pays per unit price p_i. In the second period, the only cost the mills bear is the price they pay to the farmers. In the first period, mills make the investment to target farmers. Consider investments as setting up a weighing scale, transportation, and other facilities mills provide to farmers to deliver cane to the mill. A farmer who has been targeted by only one mill, say mill i, sells cane to only mill i, provided that the price paid by the mill is great than the cost, $p_i - \omega > 0$. If both mills target a farmer, then the farmer will sell to the mill that pays the higher price. Both mills can target any farmer, regardless of his location. A Farmer who is not targeted by any mill does not sell cane to either mill. One way of interpreting this setup in terms of hotelling model is that a farmer who is targeted by either mill pays zero transportation cost for delivering cane to the targeting mill, $t = 0$. The farmer who has not been targeted by the both mills bears prohibtively high transportation cost ($t = \infty$) and do not sell cane to any mill. Let us suppose that Mill 1 chooses to target farmers located in $[0, \delta_1]$ sub-interval, where $\delta_1 \leq 1$. Mill 2 targets farmers on $[1 - \delta_2, 1]$, where $\delta_2 \leq 1$. For mills, the investment in the first period is simply choosing δ_i, where $i = 1, 2$ and $0 \leq \delta_i \leq 1$. Making an investment to target farmers is costly and the cost of investment is given by $\eta C(\delta_i)$, where $\eta > 0$ and $C(.)$ satisfies $C(0) = 0$, $C'(.) > 0$ and $C''(.) \geq 0$. Finally, I assume that $\eta C'(\delta_i) < \omega$. This implies

[2] ω could represent the costs borne by the farmer.

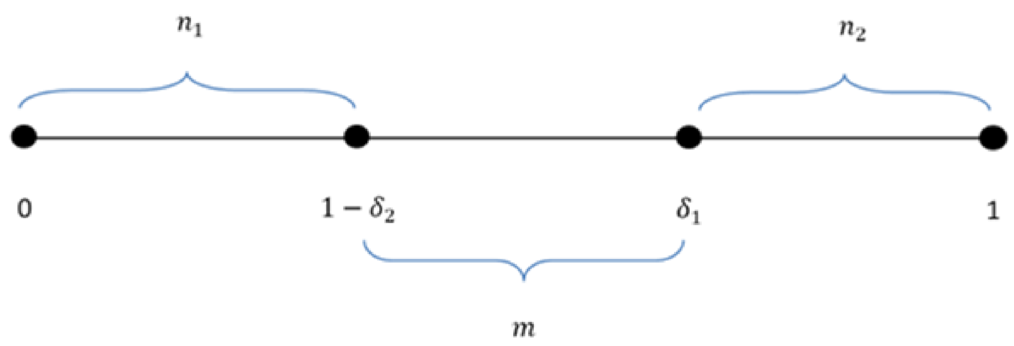

Figure 1: Captive Segment (n_i) and Contested Segment (m). $\delta_1 + \delta_2 > 1$

that the marginal cost of investment is less than the valuation of cane by farmers. In the first period, mills simultaneously choose their captive segments, δ_i. In the second stage, mills simultaneously compete in prices by setting prices, p_i and p_j. Let π_i be mill i's profit gross of investment cost, $\pi_i = (R - p_i)S_i(p_i, p_j)$. $S_i(p_i, p_j)$ is the supply of cane to mill i. The solution concept used is subgame perfect equilibrium.

3 Price Competition

In the second period, mills take δ_1 and δ_2 as given and compete in prices. Consider any combination of δ_1 and δ_2 such that $\delta_1 + \delta_2 > 0$. Let $n_i = \min(\delta_i, 1 - \delta_j)$, $j \neq i$, denote the mass of farmers captive to mill i. In other words, n_i is mill i's captive segment. The contested segment of the market, where both mills compete, is defined as: $m = \max(\delta_i + \delta_j - 1, 0)$. I now consider three market structures defined by the different combination of captive farmers.

If there is no contested segment, $m = 0$, then both mills act as monopsonies and pay the monopsony price, $p_1 = p_2 = \omega$ and profits are given by $\pi_i = (R - \omega)n_i$, $i = 1, 2$.

If at the other extreme there is no captive segment, $m = 1$ and $n_1 = n_2 = 0$, then we have the case of Bertrand-type competition and profits of both mills are $\pi_1 = \pi_2 = 0$.

As shown by Narasimhan (1988), if $0 < m < 1$, then there is no equilibrium in pure strategies. If mill i has a lower price than j, $p_i < p_j$, then i can raise its price and both mills compete till prices rise to R and both mills earn zero profits. However, mills can instead earn positive profits by buying from their own captive segments and offering the monopsony price. Both mills offering the monopsony price can also not be an equilibrium since a deviant firm can raise its price and capture the entire m. Hence, there is no equilibrium in pure strategies, but there is a mixed strategy equilibrium when $0 < m < 1$. For the case of duopoly, mixed strategy equilibrium has been analysed by Narasimhan (1988). Below I provide the intuition behind the equilibrium.

Given n_i and m, suppose that $\overline{p}_i$ denotes the critical price such that if mill i offers a price above $\overline{p}_i$, then i's profits are less than what it could have earned by buying entirely from the captive segment at the monopsony price. $\overline{p}_i$ is given by:

$$(R - \omega)n_i = (R - \overline{p}_i)(n_i + m) \tag{1}$$

which implies:

$$\overline{p}_i = R - \frac{(R - \omega)n_i}{(n_i + m)}, i = 1, 2 \tag{2}$$

A mill i will never pay any price above $\overline{p}_i$. If $n_i = 0$, then $\overline{p}_i = R$ and mill i makes zero profit, as discussed above. If $m = 0$, then $\overline{p}_i = \omega$, monopsony price and i makes monopsony profits. If $\overline{p}_i > \overline{p}_j$, then i will offer a higher price than j. Note that from expression (2) we know that $\overline{p}_i > \overline{p}_j$ if and only if $n_i < n_j$. This implies that the mill with a smaller captive segment competes more aggressively in price competition. Now I can characterize the Nash equilibrium. Suppose $\overline{p}_i \geq \overline{p}_j$ and $n_i \leq n_j$ then the support for equilibrium prices for both mills is given by $[\omega, \overline{p}_j]$. Moreover, when $n_i \leq n_j$ mill j offers the monopsony price, $p_j = \omega$, with positive probability. Firm i with a smaller captive segment offers a higher price than p_j with probability 1, when j offers the monopsony price. Thus, mill j stays in the captive segment of the market and makes monopsony profits: $(R - \omega)n_j$. Mill i, with a smaller captive segment serves its captive segment and the contested segment at price $\overline{p}_j$. Proposition 3.1 below is due to Narasimhan (1988) and summarizes price competition in the second stage of the game.

Proposition 3.1 *Suppose m and n_i are defined as above, then the equilibrium behaviour of mills in the price competition stage is give by:*
1) If $n_i = n_j = 0$, then $p_i^* = p_j^* = R$ and $\pi_i^* = \pi_j^* = 0$,
2) If $m = 0$, then $p_i^* = p_j^* = \omega$ and $\pi_i^* = (R - \omega)n_i$ and $\pi_j^* = (R - \omega)n_j$,
3) If $n_i \leq n_j$ and $m \geq 0$, then the support of equilibrium prices is same for both firms $[\omega, \overline{p}_j]$ and $\pi_i^* = n_j \frac{m+n_i}{m+n_j}(R - \omega)$ and $\pi_j^* = (R - \omega)n_j$
where π_i^* is calculated by substituting $\overline{p}_j$ in π_i.

4 Strategic Investment

In this section, I consider the first period's strategic investment decisions by mills. Both mills simultaneously invest in the market to choose the market coverage, or captive segments (δ_i, δ_j). In the first period, mills' payoffs, $\Pi = (\Pi_i, \Pi_j)$, are given by equilibrium profits from the second stage of the game, given in the Proposition 3.1, net the investment cost, $\eta C(\delta_i)$. Formally,

$$\Pi_i(\delta_i, \delta_j) = \pi_i^* - \eta C(\delta_i)$$

Now let us suppose that mill j chooses some δ_j for a given investment decision by mill i, δ_i. If δ_j is in the range of $(1-\delta_i)$, then the market is completely fragmented and in the second period both mills act as monopsonies. Both mills buy from their captive segments and earn monopsony profits. However, if j chooses $\delta_j > (1-\delta_i)$, then it can increase the supply of cane but faces price competition from mill i in the second period. Note that if δ_j is greater than both δ_i and $(1-\delta_i)$, then we have a situation where the competitive segment exists and the captive segment of mill j is larger than that of mill i, $n_j > n_i$. In this case, we know from the previous section that mill j will be less aggressive in the price competition and retreat to its captive segment, $(1-\delta_i)$, and buy cane at the monopsony price. Furthermore, the investment is costly, and targeting farmers beyond $(1-\delta_i)$ gives mill j strictly lower net profits than if it targets exactly $(1-\delta_i)$ by setting $\delta_j = (1-\delta_i)$. Hence mill j will never choose δ_j greater than $max\{(1-\delta_i), \delta_i\}$. Now if mill j sets δ_j such that $\delta_j > (1-\delta_i)$, then δ_j must be between $((1-\delta_i), \delta_i)$ and $n_j \leq n_i$ and profits of mill j in the first period will be given by:

$$\Pi_j(\delta_j, \delta_i) = n_i \frac{m + n_j}{m + n_i} (R - \omega) - \eta C(\delta_j)$$

Substituting the values of n_i, n_j and m gives us:

$$\Pi_j(\delta_j, \delta_i) = (1-\delta_j) \frac{(\delta_i + \delta_j - 1) + (1-\delta_i)}{(\delta_i + \delta_j - 1) + (1-\delta_j)} (R - \omega) - \eta C(\delta_j)$$

$$\Pi_j(\delta_j, \delta_i) = \frac{\delta_j (1-\delta_j)}{\delta_i} (R - \omega) - \eta C(\delta_j) \quad (3)$$

Now taking the derivative of (3) with respect to δ_j gives:

$$\frac{\partial (\Pi_j(\delta_j, \delta_i))}{\partial \delta_j} = \frac{(1-2\delta_j)}{\delta_i} (R - \omega) - \eta C'(\delta_j) \quad (4)$$

To evaluate the best response function of mill j, $\delta_j(\delta_i)$, we set expression (4) equal to zero and implicitly differentiate $\delta_j(\delta_i)$ with respect to δ_i:

$$\frac{\partial \delta_j(\delta_i)}{\partial \delta_i} = \frac{\eta C'(\delta_j(\delta_i))}{-2(R-\omega) - \eta \delta_i C''(\delta_j(\delta_i))} < 0$$

Hence the best response function $\delta_j(\delta_i)$ is strictly decreasing in δ_i.

We now claim that mill j finds it optimal to impinge on the territory of mill i if and only if i claims a share of market that exceeds a critical value, δ_c.

$$\delta_c = \frac{(R-\omega)}{2\,(R-\omega) - \eta C'(1-\delta_c)}$$

Lemma 4.1 *The best response function of mill j, $j = 1, 2$ and $i \neq j$, is given by:*

$$\begin{aligned} \delta_j(\delta_i) &= (1-\delta_i) \quad if\ 0 \leq \delta_i \leq \delta_c \\ \delta_j(\delta_i) &> (1-\delta_i) \quad if\ \delta_c < \delta_i \leq 1 \end{aligned}$$

Proof. Suppose mill i targets a market share of δ_i. Now for mill j evaluating the derivative in equation (2) at $\delta_j = (1-\delta_i)$ gives us the following expression:

$$\Pi'_j(1-\delta_i) = \frac{(1-2(1-\delta_i))}{\delta_i}(R-\omega) - \eta C'(1-\delta_i) \tag{5}$$

Expression (5) can be negative or positive depending on the value of δ_i. Setting (5) equal to zero and solving for δ_i gives us the critical value, δ_c, that determines the sign of (5).

$$\delta_c = \frac{(R-\omega)}{2\,(R-\omega) - \eta C'(1-\delta_c)} \tag{6}$$

$\Pi'_j(1-\delta_i) \leq 0$ at $\delta_j(\delta_i) = (1-\delta_i)$ if and only if $\delta_i \leq \delta_c$. If $\delta_i > \delta_c$ then the best response $\delta_j\,(\delta_i) > 1-\delta_i$ is obtained by setting the expression (4) equal to zero:

$$\frac{(1-2\delta_j\,(\delta_i))}{\delta_i}(R-\omega) - \eta C'((\delta_i)) = 0$$

■

It can easily be shown that $0 < \delta_c < 1$ and $\delta_c > 1/2$. I now characterized the equilibrium of the first stage of the game. Proposition 4.1 below gives the set of equilibria for the investment stage of the game.

Proposition 4.1 *In the first stage, the set of pure strategy equilibria, $\delta^* = (\delta_i, \delta_j)$, is given by:*

$$\delta_1 + \delta_2 = 1,\ and\ (\delta_i)_{i=1,2} \in [(1-\delta_c), \delta_c]$$

This set includes equal captive segments, i.e. $\delta_i = \delta_j = 1/2$.

Proof. From Lemma 4.1 we know that when $\delta_i \leq \delta_c$ the unique best response of mill j is to set $\delta_j = 1 - \delta_i$. Hence any segmentation (δ_i, δ_j), where $\delta_i + \delta_j = 1$ and $(\delta_i)_{i=1,2} \in [(1-\delta_c), \delta_c]$ is an equilibrium. Now let us consider if $\delta_i > \delta_c$, then for j the optimal response is to set $\delta_j > (1 - \delta_i)$. Suppose i sets $\delta_i = \delta$, where $\delta > \delta_c$. Let us denote mill j's best response to δ as $\delta_j(\delta) = \widehat{\delta}$. Note that $\widehat{\delta}$ will be greater than $1-\delta$, $\widehat{\delta} > 1 - \delta$. As the best response of mill i $\delta_i(\delta_j)$ is strictly decreasing, $\delta_i(\widehat{\delta})$ is smaller than $\delta_i(1-\delta)$. However, we know that $\delta > \delta_c > 1/2$ which implies that $1 - \delta < 1/2$, so $\delta_i(1-\delta) = \delta$. Therefore, $\delta_i(\widehat{\delta}) < \delta$ which implies that there is no equilibrium segmentation (δ_i, δ_j) where mill i sets $\delta_i > \delta_c$. ■

Proposition 4.1 states that in equilibrium the market will be completely segmented, and both mills will choose monopsony prices in their captive segments. Note that we can also identify the range of payoffs for both mills. For mill 1 the best allocation (highest payoff) is when it chooses $\delta_1 = \delta_c$ and mill 2 chooses $\delta_2 = (1-\delta_c)$, note that δ_c is always greater than $1/2$ for $\eta > 0$. The lowest payoff for mill 1 is when $\delta_2 = \delta_c$ and $\delta_1 = (1 - \delta_c)$. Similarly, we can define the range for mill 2.

The marginal cost parameter η plays an important role in determining the equilibrium. When η approaches 0 the critical value δ_c becomes $1/2$ and the only equilibrium is $\delta_i = \delta_j = 1/2$. On the other hand, when η increases the set of equilibria increases and eventually any allocation such that $\delta_i + \delta_j = 1$ can become an equilibrium. $\delta_i = \delta_j = 1/2$ is an equilibrium for all $\eta > 0$. Finally, since every equilibrium is a complete segmentation, mills extract the entire surplus.

5 Price Floor

In this section, I consider the effect of a price floor on mills' investment decisions. A price floor p^f is binding on mill i if its optimal price is below the price floor. First, recall that if mill i has a smaller captive segment, then it tends to pay a higher price than mill j, as $\overline{p}_i > \overline{p}_j$. This implies that if p^f binds on mill i, then it binds on mill j as well. Secondly, as m goes to zero, both mills tend to pay the same price, the monopsony price, ω. Thus any $p^f > \omega$ will bind on both mills as m becomes sufficiently small. In the first period of the game, mills choose the captive segments simultaneously, and profits in the first period, $\Pi_i(\delta_i, \delta_j, p^f)$, are now a function of captive segments and the price floor.

$$\Pi_j(\delta_j, \delta_i, p^f) = \frac{\delta_j (1 - \delta_j)}{\delta_i} \left(R - p^f\right) - \eta C(\delta_j)$$

An equilibrium in the first stage is choosing a pair of investment decisions (δ_i^*, δ_j^*) such that it maximizes $\Pi_i(\delta_i, \delta_j, p^f)$. We know from the previous section that the best response function of mill j depends on the critical value of δ_i, δ_c. After the imposition of price floor, p^f, the new critical value is:

$$\delta_c^f = \frac{(R - p^f)}{(2(R - p^f) - \eta C'(1 - \delta_c'))} \tag{7}$$

First, note that δ_c^f remains greater than $1/2$ and second, δ_c^f can be greater or smaller than δ_c depending on the different values of p^f. Comparing (6) with (7) gives us the following relationship between p^f and δ_c^f:

$$\begin{aligned} \delta_c^f > \delta_c \quad if\ p^f > \tilde{p} \\ \delta_c^f < \delta_c \quad if\ p^f < \tilde{p} \end{aligned}$$

where $\tilde{p} = R - (R - \omega)\frac{C'(1-\delta_c^f)}{C'(1-\delta_c)}$ and satisfies the condition $\tilde{p} > \omega$ when $C'(1 - \delta_c^f) < C'(1 - \delta_c)$. If the price floor is high enough, then the critical value, δ_c^f, that makes the investment beyond $1 - \delta_j$ optimal is greater after the imposition of the price floor. Proposition 5.1 below states that mills' investment decisions in the first stage will not change after the imposition of the price floor.

Proposition 5.1 *After the imposition of the price floor, mills' optimal investment decisions do not change.* $\delta^* = (\delta_i^f, \delta_j^f) = (\delta_i, \delta_j)$.

Proof. After the imposition of price floor, the best response function of mill i, $i = 1, 2$ and $i \neq j$, is given by:

$$\delta_i(\delta_j) = (1 - \delta_j) \quad if \quad \begin{cases} 0 \le \delta_j \le \delta_c \le \delta_c^f \\ 0 \le \delta_j \le \delta_c^f \le \delta_c \\ 0 \le \delta_c \le \delta_j \le \delta_c^f \end{cases}$$
$$\delta_i(\delta_j) > (1 - \delta_j) \quad if \quad \begin{cases} 0 \le \delta_c \le \delta_c^f \le \delta_j \\ 0 \le \delta_c^f \le \delta_c \le \delta_j \\ 0 \le \delta_c^f \le \delta_j \le \delta_c \end{cases}$$

The best response will only change in two cases: 1) It was not optimal to investment beyond $1 - \delta_j$ before the price floor was imposed and also not after, $0 \le \delta_c \le \delta_j \le \delta_c^f$, the third line. In this case, no investment will take place as it is no longer optimal now. 2) It was not optimal to invest beyond $1 - \delta_j$, but it is optimal after the implementation of a price floor, $0 \le \delta_c^f \le \delta_j \le \delta_c$, the last line. In this case, the best response is to invest. However, noting the fact that the critical value, δ_c^f, remains greater than $1/2$ implies that the same argument can be applied as in the Proposition 4.1 and hence no investment beyond $1 - \delta_j$ will take place. Thus, the investment decisions remain the same. $\delta^* = (\delta_i^f, \delta_j^f) = (\delta_i, \delta_j)$ ■

The intuition for Proposition 5.1 is as follows. Both mills act as monopsonies without the price floor and the price floor makes them worse off in the second period as their profits are reduced. Increasing investment in the first period and starting a price competition in the second period makes mills, even more, worse off. Hence, the optimal response is not to change the investment decisions.

6 Conclusion

Basu and Bell (1991) developed an argument that rural markets in the developing countries can best be studied as fragmented markets. These markets are often divided into captive and contested segments due to informational, institutional or locational reasons. In this chapter, I studied the sugarcane market of Pakistan and showed that these rural markets can end up in the complete segmentation of the market. Mills target farmers by investing in infrastructure and procurement logistics and create captive segments in the market. In a two-period game, set of potential suppliers for mills were endogenously determined. The set of targeted farmers may overlap, but in equilibrium I showed the market is completely segmentized into disjoint sets. Mills enjoy complete monopsony in the captive segments and pay the monopsony price. The actual allocation of equilibrium depends on the marginal of investment. As the marginal cost decreases, the market gets divided equally between firms. To protect farmers, the government sets the price floor. The price floor reduces mills' profits and increases revenue for the farmers but it has no effect of the segmentation of the market.

Chapter III

Collusion or Historical Inertia: Weight vs Sucrose Pricing in the Sugarcane Market of Pakistan

> *Individuals need not make the right trade-offs. And whereas in the past we thought the implication was that the economy would be slightly distorted, we now understand that the interaction of these slightly distorted behaviors may produce very large distortions. The consequence is that there may be multiple equilibria and that each may be inefficient. Hoff and Stiglitz, 2001*

1 Introduction

Pakistan is the 5^{th} largest sugarcane producer in the world in terms of area under cane cultivation, but 15^{th} in terms of sugar production. Pakistan stands almost at the bottom in the world ranking in terms of per hectare yield. Sugar recovery is slightly above 8%, whereas in many countries, it ranges from 12 to 14 percent (FAS-USDA, 2009). One of the reasons for the poor performance by Pakistan's sugar industry is the low quality of cane. In this chapter, I argue that this may be due to the pricing structure of the market. Sugarcane delivered to the processing mills is priced entirely on the basis of weight and no consideration is paid to the quality of cane. However, the quality of cane, as measured by the sucrose content, is the most important determinant of sugar production and profits of the mills. Despite universal recognition that the quality of cane needs to be improved, why mills do not give any price incentives to farmers is a conundrum. In a recent competition assessment study, the Competition Commission of Pakistan (CCP) raised similar concerns by blaming mills for not adopting a readily available technology to measure the sucrose content of cane: "*appropriate technology (Core Sampler) is readily available and extensively used in most countries, it is not utilized in Pakistan due to the lack of an entrepreneurial spirit on the part of the mill-owners.*" *(CCP 2009, p23)*. In spite of conducting an extensive investigation in the sugar market, the CCP's report does not provide an explanation for this puzzling pricing behaviour by mills.

In this chapter, I argue that mills' behaviour can be understood as an equilibrium of a properly specified pricing game. The structure of the game I shall propose reflects the particular technology of the industry. After harvest sugarcane becomes a quickly perishable crop. It starts losing moisture immediately after harvest and after 72-96 hours the chemical reactions start the inversion of sucrose in harvested cane. Post-harvest deterioration of cane requires processing of cane not too late after harvest to maximize production (Rakkiyappan et al., 2009). This is the reason why mills generally do not buy cane from farmers who are located too far from the mill. However, some delay may actually be profitable for the mills. While cane starts losing moisture (tonnage) immediately after harvest, the sucrose content as a percentage of the mass in staling cane reaches its highest at $72-96$ hours, depending on the age of the crop. From the mill's perspective, this implies that the value of the cane remains constant before sugar inversion starts, but the cost of purchasing cane is reduced if it pays farmers by weight. Since the price of cane is solely linked to its weight, a certain time delay can increase mills' profits. This is the key insight on which I build the model in Section 3.

In Section 3 below, I present a two-stage pricing game to capture mills' pricing behaviour. In the first stage, two mills choose between two pricing regimes; weight pricing and sucrose pricing. Weight pricing disregards the sucrose content in the cane and pays farmers entirely on the basis of weight of the cane. Sucrose pricing pays farmers on the basis of the sucrose content in the cane and pays no consideration to the weight. Once mills have chosen the price regime, they compete in prices. While mills interact with each other strategically, farmer-mill interaction is non-strategic. Farmers observe the prices chosen by the mills they could deliver to and choose which mill to take their crop to. The model implies that for a given sucrose content level, mills' profits will always be higher under the weight pricing regime as compared to the sucrose regime. This is due to the fact that moisture loss implies that the effective transportation cost paid by the farmers is higher under pricing by weight regime. Therefore, pricing by weight reduces the intensity of competition among mills. Mills pay relatively lower prices and make higher profits at the expense of farmers.

Under some plausible assumptions about the parameters of the model, the game simplifies to a coordination game between mills at the first stage of the game. The most crucial parameter is the evaporation rate s. In my numerical calculation, I take s to vary between 5 to 10%, in line with scientific studies. In this duopsony model, there are two pure strategy equilibria: both mills pricing by weight and both pricing by sucrose content. However, weight pricing is always payoff-dominant and sucrose pricing is risk-dominant. Keeping the transportation cost and the value of cane to mills constant and reducing the evaporation rate from 10 to 5 percent makes sucrose pricing a weakly dominant strategy but weight pricing remains payoff-dominant equilibrium. This result may suggest that mills coordinate on weighting pricing. This conclusion seems especially plausible when mills are regularly involved in delaying weighing and crushing the delivered cane.

However, one cannot rule the possibility that selection of the weight pricing equilibrium is due to historical inertia rather than explicit or implicit collusion. To check this possibility, I assume parameter values that would capture the historical condition of the market. In the past, transporting cane to mills would have not only been harder but also more costly to farmers as the transport infrastructure would have been underdeveloped and there were fewer mills in the market. Therefore, I assume a higher evaporation rate, $s = 15\%$, and also a higher transportation cost. With these parameters, the model generates a single equilibrium in the first stage, both mills pricing by weight. This implies that historically weight pricing might have been the only equilibrium and as infrastructure developed and number of mills increased in the market, transportation costs and evaporation rate reduced, sucrose pricing also became a possible equilibrium.

Whether mills have coordinated to pay by weight or this is due to historical inertia, weight pricing provides no incentive to farmers to improve the quality of the cane which also adversely affect mills with low recovery rates. The industry seems to be stuck in an equilibrium where mills have no incentive to switch to sucrose pricing and given weight pricing, farmers make no investment in the quality of the cane. Given the quality of the cane, mills' profits are maximized by opting for weight pricing. This is a classic coordination failure due to complementaries. Coordination failure has a long tradition in development economics, starting from Paul Rosenstein-Rodan's (1943) classic paper on the industrialization of Eastern Europe[3]. Under this view, for some initial condition, even though all players may be aware that there is another equilibrium at which each player will be better off, players are unable to coordinate the complementary actions necessary to attain that equilibrium (Hoff and Stiglitz, 2001).

Our theoretical structure in the presence of the multiplicity of equilibria has a striking policy implication. Given that the government already intervenes in the market by setting a price floor for the weight regime, I show that if the government sets the price floor high enough such that it makes mills, at least, indifferent between weight and sucrose pricing, then mills will have no incentive to stick to weight pricing. The policy should be used as a device to move the industry from

[3]Ray (1998) provides an excellent survey of this literature.

one equilibrium to another. Once the mills choose the sucrose pricing it becomes self-enforcing. This implies that the policy need not be permanent and becomes impotent once the new equilibrium is achieved.

The rest of the chapter is structured as follows. Section 2 gives a brief review of the market structure of Pakistan's sugarcane market. I explain the pricing and incentive structure in the market. It also briefly explains the production process of sugar and post-harvest deterioration of sugarcane. Section 3 describes the theoretical framework used to explain mills' pricing and equilibrium behaviour. Section 4 gives the policy implications from the analysis in section 3. Finally, section 5 concludes.

2 Sugarcane Market in Pakistan

Sugarcane is one of the most important industrial and cash crop in Pakistan. Its share in value-added by major crops has ranged between 10-13 percent during the last five years. Cane is grown on over a million hectares and provides the raw material for Pakistan's 84 sugar mills – which comprise the country's second largest agro-industry after textiles. In addition to sugar, sugarcane produces numerous valuable by-products, such as alcohol used by pharmaceutical industry, ethanol used as a fuel, bagasse used for paper and fuel, chip board manufacturing, and as a rich source of organic matter for crop production (APCom, 2006).

Historically, most mills were public enterprises and each mill was granted an exclusive zone around the mill to purchase crop. However, the market went under considerable change when reforms and liberalization started in 1987. Farmers were allowed to sell their crop to any mill and the zoning system was completely abolished. All public sugar mills were privatized and entry of new mills was encouraged. Consequently, there was a massive surge in investment. The increase in competition among mills and an upward trend of support price have increased farmers' profits, but on average the sugar recovery rate has not increased. Furthermore, the industry suffers from excess capacity. Most of the mills are producing only $50-60$ % of their output capacity. Despite this under-utilization, the number of mills has increased from 43 in 1987 to 84 in 2009.

A sugar mill operates for 4-5 months (December to April) during the processing season each year. Mills buy sugar cane from a large number of small farmers from surrounding villages and there is hardly any vertical integration between field and mills. This is in contrast to other major sugar producing regions, Brazil, Africa, Australia and Caribbean countries, where there is high vertical integration and farm size is extremely large compared with Pakistan and South Asia. For example, in Australia the average sugarcane farm is 100 hectares and in Pakistan, it is just 3 hectares (SDPI, 2012 and USDA-FAS, 2015). In comparison with other major sugar producing regions, historically the land in South Asia was already settled by a large number of peasant farmers that the colonial government did not want to displace. As a consequence, South Asian cane cultivation is still carried out by large numbers of small farmers (Amin, 1984). There are more than 500 thousand farms under sugarcane cultivation across three provinces in Pakistan. A cane farmer, assuming the average farm size and cane yield, produces nearly 50 ton/hectares of sugarcane in a year, whereas the capacity of a typical mill is nearly 5000 tons of cane per day (SDPI, 2012). This big difference in the size of the typical farm and the typical mill justifies the assumption in our model that mills have all the bargaining power, and hence farmers are price takers. What protects the farmer from mill exploitation is the competition among the mills. For this reason, stimulating competition among the mills can be very important.

To protect and represent sugar mills' interests, mills have established the Pakistan Sugar Mill Association (PSMA). Recently, the Competition Commission of Pakistan has accused PSMA of leading a cartel in the sugarcane and the sugar market. According to the commission's report, mills were working "collusively and collectively" in both markets (CCP, 2009).

2.1 Technology of Sugarcane Processing

Sugar production involves both farmers and processing mills. Farmers grow, harvest, and then transport cane to the mill or to the weighing stations established by mills. Sugarcane is a water and fertilizer intensive crop that is harvested yearly. Farmer's actions such as choice of a variety of sugarcane, timing, amount and type of fertilizer, provision of adequate water supply, and pest control directly determine the quality and sucrose content of the cane. The quality of sugarcane, measured as sucrose content in the cane, is considered to be the most important determinant of mill's profitability. It is nearly impossible for mills to verify if these actions were taken appropriately by farmers. Once the cane arrives at the processing mill, it is crushed to extract juice and then boiled till it crystallizes as raw sugar. Raw sugar is then washed and filtered to remove non-sugar ingredients and colour. The amount of sugar that a mill can extract from cane not only depends on the sucrose and water content of sugarcane, but also on the efficiency, hygiene, and organization at the mill. The cost of acquiring sugarcane accounts for $80 - 85$ % of the total cost of sugar production.

Once farmers harvest the cane they transport it to the weight stations established by mills. Given the perishable nature of the cane, mills and farmers coordinate cane harvesting. A mill decides on a time window during which it will purchase cane from a particular village and let it be known through its agent in the field, Naseer (2007).

2.2 Pricing and Incentive Structure

Pricing of the cane is one of the most controversial issues in Pakistan's agriculture policy. Currently, farmers are paid exclusively by weight of cane (tonnage). The quality of the cane is not incorporated into the pricing. Despite universal recognition that the quality of the cane needs to be improved, mills do not give any price incentives to farmers to grow better quality cane.

Mills often claim that their technical staff conducts a visual inspection of cane to check the quality and sign of nutrient stress when the cane reaches the mill. Once the quality is assessed by visual inspection, mills pay an informal premium to farmers to encourage them to raise the quality of cane. However, no scientific method is employed to check the sucrose content of incoming cane. Technology for measuring quality as a percentage of sucrose content is widely available, cheap, and used in other regions. Naseer (2007) tests the hypothesis that if the price paid to farmers has a quality component, then the price farmers receive ought to relate to quality enhancing inputs, fertilizer and irrigation usage. Using household data from Punjab and Sindh, two provinces that constitute almost 80% area under sugarcane production in Pakistan, he does not find evidence for price returns for quality enhancing inputs.

Provincial governments in Pakistan intervene in the market by estimating the cost of producing sugarcane and then setting a price floor after consulting farmers and mills. The rationale for government intervention is to protect farmers against the monopsony power of mills and to ensure that farmers do not make losses on their production. The Pakistan sugar mill association has repeatedly urged the government to abolish the price floor. Historically, Indian sugar mills have also paid by weight, however, since 2009 the government of India changed policy and the Statutory Minimum Price (SMP) was replaced by the Fair and Remunerative Price (FRP)[4]. In the same year Pakistan also announced a new policy but ironically without changing the sugarcane pricing mechanism. FRP not only takes account of sugar but also of all-India recovery rate of sugar from sugarcane (CACP, 2014).

[4]In the Indian market, about 50% of the 550+ sugar mills are either Government owned and operated or managed by farmers' co-operative societies.

In Pakistan, sugar mills in Sindh once made premium payments based on sucrose content, above the price floor, to all farmers (CCP, 2009). This, however, creates a classic incentive problem, where each farmer is paid a premium on the overall recovery rate achieved by all mills in any particular year. Hence, farmers have incentives to free-ride on others.

2.3 Post-harvest Deterioration of Sugarcane

Sugarcane is a highly perishable crop. After harvest, a series of physiological events start deteriorating cane. Deterioration is often exacerbated by transportation, storage, method of harvesting, and climatic conditions. From field to processing, the cane can considerably lose tonnage and quality. There are three different reasons for the deterioration of sugarcane: loss in moisture, biochemical deterioration, and microbial deterioration (Solomon, 2009). The first adversely affects the farmers and the other two the mills.

Right after the harvest, cane rapidly starts losing moisture, which results in the reduction of cane tonnage. There is a steady increase in moisture loss from 3% within 24 hours of harvest to 10% within 72 hours in subtropical regions (Rakkiyappan et al. 2009 and Solomon, 2009). Loss of moisture from harvested cane reduces its weight and hence the payment to farmers.

Biochemical deterioration involves inversion of sucrose. After harvest, sugarcane cells and respiration get damaged. The exposed sucrose is subjected to physiological acidic pHs that can start its acid inversion, and the higher the acidity the faster the inversion. Many hydrolytic enzymes are also activated after harvest that eventually reduce the quality of the cane.

The principal cause of deterioration to cane quality and sucrose recovery is microbial deterioration, caused by lactic acid bacterium, *Leuconostoc mesenteroides*. The microbes infect cane wherever the stalk is cut. It rapidly colonizes the damaged tissue which is followed by falling sucrose content, juice purity, and pH. Microbial infection is linked with humidity, temperature, mud attached to the culm, factory hygiene and delay between harvest and processing. This accounts for 93% of quality deterioration of cane (Van Heerden et al., 2014). Biochemical and microbial deterioration affect sugar recovery and profitability of the processing mill.

It is important to emphasize that while moisture loss starts immediately, the sucrose content (measured as Pol %) starts decreasing after a certain time. As moisture evaporates, sucrose as the percentage of mass reaches highest after $72-96$ hours of harvest and then it starts reducing rapidly (Rakkiyappan et al., 2009). Any delay in crushing cane reduces the moisture and weight of cane. Since the price of the cane is solely linked to its weight, delay decreases the revenue farmers receive. Farmers avoid supplying to a mill that is located beyond a day's travel. Mills too generally do not buy from farmers that are located too far from the mill. The theoretical model in section 3 below is built on the premise that after the harvest mill can start crushing the cane before the sucrose inversion starts. Throughout the analysis, I assume that the sucrose content remains same. This assumption is based on the fact that sucrose content only starts reducing after 3 to 4 days and mills, being aware of this, do not buy cane from farmers located too far from the mill.

3 The Model

Consider a rural region in a developing country where cane farmers are located uniformly over a unit interval, $[0, 1]$. There are two identical sugar processing mills, each located at one end of the interval. Mill 0 is located at 0 and mill 1 is located at 1. The only difference among mills is their location. Each farmer grows and supplies one unit of cane to the mills and bears the transportation cost. For simplicity, I assume linear transportation cost. The transportation cost per unit of distance is t, the total cost of transporting one unit of cane is tx when the farmer is located at x. Two mills compete with each other in two stages. In the first stage, both mills decide which price regime to adopt, weight or sucrose pricing. Weight pricing gives no consideration to the sucrose content in the cane and pays solely by weight. Sucrose pricing pays only for the sucrose content in a unit of cane, which I assume is fixed throughout the analysis. In the second stage, given their choice of price regime, mills compete in prices. Formally in the first stage each mill's action set is $S_i \in \{Weight,\ Sucrose\}_{i=0,1}$ and in the second stage mill's choose $p_i^k \in [0, \infty)_{i=0,1}^{k=w,s}$, where k is the price regime chosen by mill i in the first stage. p_0^s denotes mill 0 pays farmer by sucrose content in the cane and p_0^w denotes mill 0 pays by weight of the cane. The two prices may not directly be comparable. At each stage, mills choose their strategies simultaneously. I look for the subgame perfect equilibrium in this two-stage game. Our strategy will be to first fix the pricing regimes for both mills and then find the equilibrium prices at the second stage. Given these equilibrium prices, I then find the equilibrium pricing regime at the first stage.

A farmer's payoff is given by the price he receives net of the transportation cost. I assume that the cost of growing cane for farmers is zero. Under sucrose pricing regime, the value of the cane is determined by the sucrose content of the cane and is assumed be constant. The payoff of a farmer located at location x and receiving payment by sucrose content is given by:

$$\nu_x = \begin{cases} p_0^s - tx & if\ cane\ is\ sold\ to\ mill\ 0 \\ p_1^s - t(1-x) & if\ cane\ is\ sold\ to\ mill\ 1 \end{cases}$$

Under weight pricing regime, I assume that the postharvest cane loses its moisture, and hence the weight, at a constant rate, $s \in (0, 1)$. If mills choose to pay by weight, then a farmer located at x receives revenue of $p_0^w(1 - sx)$ if he delivers to mill 0. Since the cane loses its moisture at a constant rate s, $1 - sx$ is the remaining proportion of the cane when mill 0 weighs the cane, and the farmer only receives the payment on this remaining proportion. As mentioned above, I assume that sucrose content does not change; it is only the moisture that evaporates. The payoff of a farmer located at x is:

$$\nu_x = \begin{cases} p_0^w(1-sx) - tx & if\ cane\ is\ sold\ to\ mill\ 0 \\ p_1^w(1-s(1-x)) - t(1-x) & if\ cane\ is\ sold\ to\ mill\ 1 \end{cases}$$

Assuming that the marginal cost of production of sugar is zero, under a given price regime, mills profits are given by

$$\Pi_i^k = (R - p_i^k)S_i^k(.)$$

Where R is the value of one unit of cane to the mill and remains fixed, and $R > t$. $S_i^k(.)$ is the supply of cane to mill i under pricing regime k. I now look for the equilibrium in this two-stage game.

4 Equilibrium

4.1 The Second Stage

In the second stage mills compete in prices for cane, for a given price regime in the first stage. I first consider the case when both mills have chosen to pay by sucrose content.

4.1.1 Both Mills Pay by Sucrose Content

It is clear from the above setup that if both mills choose sucrose pricing then the second stage of price competition is same as in the standard Hotelling model. A farmer located at $x \in [0, 1]$ will trade with mill 0 if and only if $p_0^s - tx \geq 0$ and

$p_0^s - tx \geq p_1^s - t(1-x)$. Let $\overline{x}^s$ be the farmer who is indifferent between two mills, then $\overline{x}^s$ must satisfy:

$$\begin{aligned} p_0^s - t\overline{x}^s &= p_1^s - t(1-\overline{x}^s) \\ \overline{x}^s &= \frac{1}{2t}\left(t + p_0^s - p_1^s\right) \end{aligned}$$

Hence, the supply to mill 0, S_0^s, and mill 1, S_1^s, are given by:

$$\begin{aligned} S_0^s &= \frac{1}{2t}\left(t + p_0^s - p_1^s\right) \\ S_1^s &= 1 - S_0^s \end{aligned}$$

Mills profits are then given by:

$$\begin{aligned} \Pi_0^s &= (R - p_0^s)S_0^s \\ \Pi_1^s &= (R - p_1^s)S_1^s \end{aligned}$$

Since both mills are symmetric, equilibrium prices are then given by:

$$P^{s*} = R - t$$

which gives the equilibrium profits:

$$\Pi^{s*} = \frac{1}{2}t \tag{1}$$

4.1.2 Both Mills Pay by Weight

If both mills pay by weight of the cane, then a farmer located at $x \in [0,1]$ will trade with mill 0 if and only if $p_0^w(1 - sx) - tx \geq 0$ and $p_0^w(1 - sx) - tx \geq p_1^w(1 - s(1-x)) - t(1-x)$. Since cane starts losing moisture as soon as it is harvested, farmers' revenue also decline at the rate of evaporation and the farther from the mill a farmer's location is, the more he will lose. An indifferent farmer, $\overline{x}^w$, must satisfy:

$$\begin{aligned} p_0^w(1 - s\overline{x}^w) - t\overline{x}^w &= p_1^w(1 - s(1-\overline{x}^w)) - t(1-\overline{x}^w) \\ \overline{x}^w &= \frac{t + p_0^w - p_1^w\left(1-s\right)}{2t + s(p_0^w + p_1^w)} \end{aligned}$$

Supply to mill 0, S_0^w and mill 1, S_1^w are given by:

$$\begin{aligned} S_0^w &= \frac{t + p_0^w - p_1^w (1-s)}{2t + s(p_0^w + p_1^w)} = \overline{x}^w \\ S_1^w &= 1 - S_0^w \end{aligned} \tag{2}$$

Mill 0's profit maximizing problem is:

$$\begin{aligned} \max_{p_0^w} \pi_0 &= R\overline{x}^w - p_0^w \int_0^{\overline{x}^w} (1 - sx)\, dx \\ &= \left(R - p_0^w (1 - \frac{s\overline{x}^w}{2}) \right) \overline{x}^w \end{aligned} \tag{3}$$

Setting FOC equal to zero gives the equilibrium prices and profits[5]:

$$\begin{aligned} P^{w^*} &= R(1 - \frac{s}{2}) - t(1 - \frac{s}{4}) \\ \Pi^{w^*} &= \frac{1}{2}t + \frac{s}{32}\left((12 - 2s)\, R - (8 - s)\, t\right) \end{aligned} \tag{4}$$

Comparing (1) with (4) gives the following result:

Proposition 4.1 *If both mills choose the same price regime, then the equilibrium profits are higher under the weight regime.*

$$\Pi^{w^*} > \Pi^{s^*}$$

Proof. $\Pi^{w^*} > \Pi^{s^*}$ *iff*

$$\frac{1}{2}t + \frac{s}{32}\left((12 - 2s)\, R - (8 - s)\, t\right) > \frac{1}{2}t$$

which reduces to

$$R\,(6 - s) > t\left(4 - \frac{s}{2}\right)$$

Noting that $R > t$ and $0 < s < 1$, this inequality will always hold ■

The intuition behind Proposition 4.1 is that once cane is harvested, it will immediately start losing its weight while the sucrose content remains the same. Mills' revenue from one unit of cane is kept constant under both regimes, but per unit cost of purchasing cane is lower under the weight regime. Evaporation of moisture

[5] The FOC with respect to p_0^w and the solution is given in the appendix.

increases the effective transportation cost for farmers and hence reduces the competition between mills. Higher profits under the weight regime implies that mills make higher profits at the expense of farmers by paying realtively lower prices. Farmers' revenue decreases with the increase in distance from the mill.

Next I consider the case in which one mill pays by sucrose content and the other by weight.

4.1.3 Separating Strategies

Now let us suppose that each mill follows a different strategy. Without loss of generality, I assume that mill 0 pays by sucrose content and mill 1 pays by weight. The indifferent farmer and supply to the mills is given by:

$$p_0^s - tx = p_1^w(1 - s\,(1-x)) - t(1-x)$$

$$S_0^s = \overline{x} = \frac{1}{2t + sp_1^w}\,(t + p_0^s - p_1^w\,(1-s)) \tag{5}$$

$$S_1^w = 1 - \overline{x} = \frac{1}{2t + sp_1^w}\,(t + p_1^w - p_0^s) \tag{6}$$

Expression (5) and (6) give the supply to both mills. Supply to mill 0 is higher and lower to mill 1 the higher the rate of evaporation[6]. As s increases, transporting cane to mill 1 becomes more costly to farmers. The indifferent farmer shifts to the right as supplying to mill 1 becomes less attractive under higher s. Mill 0's problem is

$$\underset{p_0^s}{Max}\;\pi_0 = (R - p_0^s)\left(\frac{1}{2t + sp_1^w}\,(t + p_0^s + p_1^w\,(s-1))\right)$$

FOC gives mill 0's best response function:

$$p_0^{s^*} = \frac{1}{2}(R - t + p_1^w(1-s)) \tag{7}$$

Mill 0 lowers its price, $p_0^{s^*}$, by $\frac{p_1^w}{2}$ if the evaporation rate goes up and increases $p_0^{s^*}$ by $\frac{(1-s)}{2}$ if p_1^w increases. Increases in the evaporation rate reduce the competition for mill 0. Mill 1's profit maximization is given by:

$$\begin{aligned}
\underset{p_1^w}{Max}\;\pi_1 &= \left(R - p_1^w(1 - \frac{s(1-x)}{2})\right)(1-\overline{x}) \\
&= \left(R - p_1^w(1 - \frac{s(\frac{1}{2t+sp_1^w}\,(t + p_1^w - p_0^s))}{2})\right)(\frac{1}{2t + sp_1^w}\,(t + p_1^w - p_0^s))
\end{aligned}$$

[6]as $\frac{\partial \overline{x}}{\partial s} > 0$ and $\frac{\partial(1-\overline{x})}{\partial s} < 0$.

Taking derivative with respect to p_1^w and setting it equal to zero and then substituting 7 gives:

$$\alpha p_1^3 + \beta p_1^2 + \gamma p_1 + \delta = 0 \tag{8}$$

where

$\alpha = \frac{1}{4}s^4 - \frac{1}{2}s^3 + \frac{5}{4}s^2$

$\beta = \frac{1}{2}Rs^3 - \frac{1}{2}Rs^2 + s^3t - \frac{5}{2}s^2t + \frac{15}{2}st$

$\gamma = 4st^2 - 3R^2s^2 - 3s^2t^2 + 48t^2 + 18Rs^2t - 20Rst$

$\delta = 2t^3 - \frac{5}{2}R^2st + 9Rst^2 - 12Rt^2 - \frac{9}{2}st^3$

Equation (7) has one real root but the explicit expression for it is unmanageable. Therefore, for finding the equilibrium, I opt for the numerical solution. To have a meaningful analysis, I keep the value of cane to mills, R, and transportation cost, t, fixed. The central parameter in the analysis is the evaporation rate and I consider two values of s, $s \in \{0.05,\ 0.10\}$, each supported by scientific studies, as reported in section 2. I start the analysis with $s = 0.10$ and then later also consider $s = 0.05$. I believe that this is the most reasonable approximation for the current state of affairs in the market. As mentioned above, most farmers in Pakistan harvest cane manually, which is time-consuming and the harvested cane will only be transported to the mill when a farmer has harvested a big enough bulk to be transported. Secondly, transporting harvested cane to the mill on the rural road network is an extremely slow process. Unlike more developed countries, where the cane is transported via train, cane in south Asia is transported by tractor and trollies which is a slow mode of transportation. Finally, mills often delay weighing of the cane even after cane reaches the mill. In light of all these factors, it is fair to assume that from harvesting to weighing of the cane at the mill on average it takes two to three days. Hence, assuming $s \in \{0.05,\ 0.10\}$ is a reasonable approximation. In our setup, the evaporation of cane is directly linked to the distance between the farmer and the mill. For any given rate of evaporation, a farmer who is closer to the mill loses less than the farmer who is located further away.

Let $R = 2t$, $t = 0.65$, and $s = 0.10$. $R = 2t$ will ensure that the entire market is covered. The choice of t depends on the properties of the Hotelling model. In the hotelling model when $t \in (0, \frac{2}{3}]$, the Nash equilibrium is unique and the competitive regime is obtained. For $t \in (\frac{2}{3}, 1]$, there is an infinity of Nash equilibria, and finally if $t > 1$, then each mill is a monopsonist (Merel and Sexton, 2010). I assume that t is close to the upper bound that implements the competitive regime and gives a unique Nash equilibrium. Substituting these values in (7) and (8) and then into respective mill's profits give the equilibrium prices and profits. For mill 0 these are

0.61, 0.35 and for mill 1 are 0.63, 0.32 respectively[7]. I conclude that if R is high enough, the transportation costs are not prohibitively high, the evaporation rate is $s = 0.10$, and mills choose different price regimes, then the equilibrium profits will be higher under sucrose pricing than weight pricing. The intuition behind this result is that supplying to mill 1 become less attractive to farmers who are distant from mill 1 relative to mill 0 because mill 1 makes the payment on the remaining weight of the cane. The evaporation rate decreases the competition for mill 0 and therefore it will offer a lower price to farmers. Matrix 1 below shows the equilibrium prices.

		Mill 1	
		Weight	*Sucrose*
Mill 0	*Weight*	0.60 0.60	0.63 0.61
	Sucrose	0.61 0.63	0.65 0.65

Matrix 1: Equilibrium Prices : R=2t=1.3, t=0.65,s=0.10

Matrix 1 shows that mill 0, paying by sucrose, offers a lower price (0.61) when the rival mill pays the farmer by weight relative to when the rival mill also pay by sucrose content; then both mills pay (0.65)[8]. Mill 1 pays a higher price when the rival opts for the sucrose pricing (0.63) relative to when the rival chooses the weight pricing (0.60) and vice versa. In the case when $s = 0.05$ the equilibrium prices are presented below.

		Mill 1	
		Weight	*Sucrose*
Mill 0	*Weight*	0.62 0.62	0.64 0.63
	Sucrose	0.63 0.64	0.65 0.65

Matrix 2: Equilibrium Prices : R=2t=1.3, t=0.65,s=0.05

I now turn to the first stage equilibrium analysis.

4.2 The First Stage

Given the equilibrium prices and profits in the second stage of the game, mills choose what price regime to follow in the first stage of the game. Matrix 3 below shows the equilibrium payoffs in the first stage under different pricing regimes

[7] All figures are rounded to 2 digits.
[8] Calculations for all matrices are given in the appendix.

when the evaporation rate is set at 10%, $s = 0.10$.

		Mill 1	
		Weight	*Sucrose*
Mill 0	*Weight*	0.36 0.36	0.32 0.35
	Sucrose	0.35 0.32	0.33 0.33

Matrix 3: Equilibrium Profits: R=2t=1.3, t=0.65,s=0.10

Matrix 3 shows that if one mill is paying by weight (sucrose), then the rival's best response is to pay by weight (sucrose)[9]. Hence, we have two equilibria (*Weight, Weight*) and (*Sucrose, Sucrose*). Our simple model generates the familiar stag hunt game in matrix 3. A mill that pays by weight takes a risk that the rival may opt to play sucrose instead of weight, and it will end up with the lowest possible profits. The rival may want to encourage farmers to produce cane that has higher sucrose content. Any mill that chooses sucrose pricing is better off if the rival plays weight instead of sucrose; however, the best response for the rival is to play sucrose. This creates a slightly different payoff structure than the standard stag hunt game; nevertheless matrix 1 produces two equilibria. Playing weight is still risky and attracts mills towards sucrose pricing equilibrium while playing weight is mutually beneficial for both mills. In fact, the game in Matrix 3 is a variant of a coordination game called the assurance problem. The assurance problem was first introduced by Sen (1967) in the discussion of appropriate discount rate, and what policy measures might help produce an optimal saving rate or investment in an intertemporal economy. Both players would like to be assured that the other will choose the weight pricing, to which weight pricing is the best response. But without sufficient confidence that this is what the rival will choose, the unique best response is sucrose pricing.

Next I reduce the evaporation rate to 0.05; this represents the case if cane is crushed relatively early. Matrix 4 below gives us the equilibrium profits from the

[9]Profit figures are rounded to 2 values. Complete calculations are given in the appendix A-1

first stage.

		Mill 1	
		Weight	*Sucrose*
Mill 0	*Weight*	0.34 0.34	0.32 0.34
	Sucrose	0.34 0.32	0.33 0.33

Matrix 4: Equilibrium Profits: R=2t=1.3, t=0.65, s=0.05

The model still retains the same two equilibria (*Weight, Weight*) and (*Sucrose, Sucrose*) and the resulting game is akin to stag hunt. However, now playing sucrose pricing is a (weakly) dominant strategy. This creates an interesting scenario where the resulting game has a prisoner's dilemma like incentive structure for both mills but multiple equilibria like the stag hunt. It suggests that individually rational mills will choose to play sucrose pricing, but mutual cooperation is also an equilibrium, unlike the prisoner's dilemma. As compared to the previous case when $s = 0.10$, the risk that if a mill plays weight and the rival may play sucrose has increased since rival is indifferent between weight and sucrose. Reduced profits under the weight pricing equilibrium relative to $s = 0.10$ and a higher risk that the rival may opt sucrose pricing increase the likelihood of (*Sucrose, Sucrose*) equilibrium. However, the weight pricing equilibrium remains payoff dominant.

The fact that the processing mills in Pakistan choose to pay by weight suggests that mills may have overcome the tension between risk and mutual cooperation and coordinate on payoff dominant equilibrium. Weight pricing, however, is not a desirable equilibrium for the industry as a whole. As mentioned above, paying by weight gives farmers no incentives to improve the quality of the cane.

5 What Creates the Persistence of Weight Pricing?

The above analysis shows that there are two pure strategy equilibria. The fundamental question is why mills opted for weight pricing. Is it that the mills coordinate and collude on the weight pricing equilibrium or is it chosen by historical inertia? Answering this question without extensive data is almost impossible, and data on processing mills is not publicly available. Secondly, the coordination game framework is generally not of much use to pin down the forces of historical inertia. Constructing a dynamic model or repeating the coordination game can generate even more equilibria, including those in which mills switch from weight pricing to sucrose pricing and then back under different strategies. However, as I show below, different parameter values, based on reasonable supposition, can shed some light on this question.

Historically the transportation cost would have been higher as the transportation infrastructure was underdeveloped and the number of mills was relatively low. Transporting cane to mills was not only costly but also harder. By transporting at a slower pace and traveling a longer distance, the cane must have lost more weight before it reached the mill. Therefore, to explain history dependence I consider the case when $s = 0.15$ and the transportation cost is $t = 0.70$[10]. Matrix 5 below gives the equilibrium profits for different price regimes. Now weight pricing is the dominant strategy and there is only one pure strategy Nash equilibrium, (*Weight, Weight*).

Mill 1

		Weight	*Sucrose*
Mill 0	*Weight*	0.40 , 0.40	0.37, 0.39
	Sucrose	0.36, 0.37	0.35, 0.35

Matrix 5 Equilibrium Profits:R=2t=1.4, t=0.70, s=0.15

One could argue that at the initial stages of development of the industry, when the infrastructure was underdeveloped and the moisture loss was high, weight price was the only equilibrium. Mills continue to pay by weight as they did in the past and they have no incentive to switch to sucrose content as long as others don't change their pricing regime. The weight pricing equilibrium could be history dependent. The lack of scientific knowledge about the physiology of the cane could have also played the role in choosing weight pricing. However, at the current stage of development, practicing delay in weighing and under-weighing the cane does indicate that mills try to increase their profits by increasing the moisture loss. If a mill observes that the rival has been delaying the weighing of cane in the past, then it may serve as a signal that the rival will stick to weight pricing. Hence, the risk of rival switching to sucrose pricing diminishes. This helps mills coordinate on

[10]Keeping the transportation cost at 0.65 and increasing s to 0.15 changes the payoff values but $(Weight, Weight)$ is the dominant strategy.

Mill 1

		Weight	*Soucrose*
Mill 0	*Weight*	0.37 , 0.37	0.34, 0.36
	Soucrose	0.36, 0.34	0.33, 0.33

Matrix 6: equilibrium profits: R=2t=1.3, t=0.65, s=0.15

weight pricing equilibrium. Coordination and collaboration through PSMA reduce this risk to a minimum even before mills start crushing the cane. The higher profits associated with weight pricing also explains the persistence of weight pricing equilibrium.

6 Policy Implications

In this section, I look at the policy implication of the above analysis. I used a two-period game to explain why mills pay by weight. Farmers and mills interact repeatedly and both players' actions in one period affect others choices in the next. As outlined in section 2 above that mills do not pay any price returns to the quality of the cane and payments to the farmer are entirely based on the weight of the cane. The low quality of the cane is the primary reason why Pakistan's sugar production is low. Both farmers and mills can take actions that can improve the overall industry. If farmers are paid by sucrose content, then they can exert more effort to improve the quality of cane and the higher the quality, the higher the payment they will receive. Mills will always prefer paying by weight, but over the long run, mills will become better off if farmers improve the quality of the cane. It will increase mills' sugar recovery. However, for a given sucrose content level mills do not have an incentive to switch away from weight pricing. I do not model the interaction between farmers and mills, but it is easy to see that this situation is also similar to a coordination game with multiple equilibria. Mills choosing to pay by weight and farmers not investing in the quality of cane, and mills paying by sucrose content and farmers investing in the quality being two equilibria. The current situation in the industry suggests that the industry is stuck in the bad equilibrium, and indicates a coordination failure, where neither party has the incentive to move away from this bad equilibrium. Can government intervention help the industry to adopt sucrose pricing regime? I consider a government intervention that is already present in the market; a price floor. Below I show that the price floor can be used to move the industry from weight pricing to sucrose pricing.

The mill will be indifferent between paying by weight or sucrose content if the equilibrium profits from weight and sucrose pricing regime are the same, $\pi^{s^*} = \pi^w(P)$. I propose that a price floor under weight pricing should be set such that it makes weight pricing profits equal to the equilibrium profits under sucrose pricing.

Equation (9) below gives the condition that makes these two profits equal.

$$\frac{1}{2}t = \left(R - p(1 - s\left(\frac{\frac{t+p-p(1-s)}{2t+s(p+p)}}{2}\right))\right)\left(\frac{t+p-p\,(1-s)}{2t+s(p+p)}\right) \tag{9}$$

The left hand side of the equation (9) is the equilibrium profits when both mills choose to pay by sucrose content. The right hand side is the profit function when both mills pay by weight. A binding price floor implies that all mills will be at least paying each farmer the price floor. The price floor that equates these two profits is given by:

$$p^f = \frac{4(R-t)}{4-s}$$

Comparing p^f with P^{w^*} shows that $p^f > P_w^*$. Using the same parameter values $R = 2t$, $t = 0.65$ and $s = 0.10$ gives $p^f = 0.67$ and $P_w^* = 0.61$. Choosing a price floor $p^f \geq \frac{4(R-t)}{4-s}$ gives mills an incentive to switch to the sucrose pricing regime, as profits from weight pricing reduce to at most Π^{s^*}. Setting a higher price floor should be viewed as a mechanism for moving the industry out of one equilibrium into another. Note that this policy change need not be permanent because once the desired price regime is adopted, no mill will have an incentive to deviate and switch to weight pricing again. This policy view is in contrast to the view that government should heavily invest in the infrastructure so that moisture loss can be minimized. My analysis shows that mills will always prefer weight pricing because, given the sucrose content, weight pricing is always more profitable. Delivering cane to the mill will always take some time and mills can deliberately delay weighing the cane, as is often practiced in Pakistan.

It is important to emphasize that I am not suggesting that the government or mills should not invest in the infrastructure to facilitate farmers' delivery of cane to mills. The argument is that investing in transport infrastructure will not give mills incentives to change their pricing regime and hence for farmers to invest in the quality of the cane. Improving the infrastructure for transportation will make mills worse off and farmers better off because farmers will be able to deliver the cane quicker than before and receive higher payments for the same quality of the cane. Secondly, improved infrastructure will increase competition among mills and farmers will be able to benefit from this increase in the competition. Finally, investing in the road infrastructure is an extremely expensive government intervention, while setting a higher price floor is costless. However, setting a higher price floor may have its own challenges. The biggest challenge will be the implementation of the new price floor. At the time of implementing the policy, it is not optimal to follow the policy, but the government is forcing mills to switch by setting a high price floor. Farmers too will have to exert more effort and invest more resources to make the quality of the cane better. Therefore, before implementing any equilibrium switching policy, the government should announce well in advance its intentions to change the policy. Farmers can choose if they want to continue growing cane and if so, then take appropriate actions to increase the quality of the cane. As mentioned above, farmers' and mills' interests have always been at odds with each other, and there is a persistent mistrust between both players. During the transition period and once the new pricing regime is adopted, the market also needs to adopt new standards and rules for transparency as sucrose content testing is conducted on the premises of mills. The industry will need to standardize testing procedures. In the past, mills have often reacted to any increase in price floor by delaying the crushing season or delaying weighing the cane. If the government does not play the intermediary role to make the transition smooth, the industry may end up with a worse outcome.

7 Conclusion

In this chapter, we asked the question: why do sugar processing mills in Pakistan pay by weight and not by the quality of the cane? The two-stage pricing game suggests that both weight and sucrose pricing can be equilibrium, but weight pricing is payoff dominant. Several practices by mills, delay in crushing, under weighing cane, the formation and functioning of PSMA, etc., indicate that mills coordinate at the weight pricing. However, as I have argued in section 4.3, the persistence of weight pricing could be due to historical inertia, and the structure of the market makes it persistent. Therefore, I cannot claim for sure that mills are involved in collusive practices, but our analysis does explain why mills stick to weight pricing. Based on the analysis, I have proposed one possible government intervention that could switch the market to sucrose pricing: setting a high enough price floor in weight pricing that could make mills at least indifferent between two equilibria. Since the sucrose pricing is equilibrium, it is self-enforcing. However, the equilibrium tipping policy needs to be carefully implemented during the transition, or it can fail badly.

Chapter IV

Intrinsic and Instrumental Reciprocity in Bilateral Informal Risk Sharing

> "How selfish soever man may be supposed, there are evidently some principles in his nature, which interest him in the fortune of others, and render their happiness necessary to him, though he derives nothing from it except the pleasure of seeing it." Adam Smith (1759)

1 Introduction

Risk is pervasive in rural communities of developing countries. Insurance and credit markets, in contrast, are often missing or incomplete. To cope with risk, households have developed many risk-coping strategies. They self-insure by saving, diversify their income and share risk by informal mutual support mechanisms. Economists have traditionally relied on rational self-interest to explain informal risk sharing arrangements. However, emotions can also play an important role in the enforcement of these informal contracts. In this chapter, I study the interaction of emotions and economic incentives in a bilateral informal risk sharing mechanism.

The literature on informal insurance has been developed to explain extensive empirical evidence that households in rural communities manage to achieve a remarkable amount of insurance, but they do not fully share the risks they face (Townsend, 1994, and many others). The literature has focused on two imperfections to explain the observed partial insurance: private information (Ligon, 1998) and lack of commitment (Coate & Ravalion, 1993; Ligon, Thomas, and Worrall, 2002). Here, I restrict my attention to limited commitment. The idea is that two households may enter into a risk-sharing arrangement to mitigate the adverse effects of the idiosyncratic risk they face when formal insurance contracts are not available. Since there is no formal mechanism of enforcement, lucky households may renege on their commitment. Therefore, these informal contracts must be self-enforcing.

This approach was first taken by Kimball (1988), who shows that farmers in rural communities may achieve risk sharing with voluntary participation. In an important paper, Coate and Ravallion (1993) used a repeated game and introduced a two-sided limited commitment framework to study informal sharing mechanism. They focus on stationary strategies; that is, strategies that depend only upon the current realization of income and not on past transfers. These models are often referred to as static limited commitment models, in contrast to dynamic models where current transfers may depend on the history of the transfer (Ligon et al., 2002).

Formalizing partial risk sharing with limited commitment in a repeated game framework provides a parsimonious way to model cooperative behaviour in rural communities. However, the set of equilibria of an infinitely repeated game is generally very large. To avoid multiplicity of equilibria, Coate and Ravallion (1993) focused on constrained efficient allocations. However, Fafchamps (2003) and Platteau (2006) have argued that the selection of equilibria depends on the bargaining power of the households and it is not always the case that the bargaining processes converge to the constrained efficient outcomes. Bargaining power may depend on the disagreement point of households, altruistic tendencies, past experiences, and a host of other ethical and emotional sentiments.

In this chapter, I analyse how emotions interact with strategic motivations to produce economic behaviour. In particular, within a static limited commitment framework, I look at the effects of players' own altruism, envy and others' expectations on the critical discount factor that is necessary to sustain risk sharing mechanisms[11]. To my knowledge, this is the first attempt to study the role of envy and expectations in the context of risk sharing. Altruistic sources of incentives in risk-sharing have been considered before. Fafchamps (2003) studies a static limited commitment model and adds a constant term to the incentive constraint to capture the effects of altruism on the set of equilibria[12]. In contrast, I use a preference structure that has altruism and envy embedded together, Fehr-Schmidt (1999) preferences. This has two advantages: firstly, altruism affects both sides of the incentive constraint, not only making the participation in risk sharing easier but also making it harder to punish defection. Secondly, I can distinguish the different roles played by envy and altruism on the set of equilibria and the critical discount factor. More importantly, I model the role of intentions\expectations in the context of risk sharing by using a psychological game theory framework. In particular, I employ Rabin (1993) and Dufwenberg and Kirchsteiger (2004) (henceforth DK) type preferences

[11]In section 5 below, I briefly discuss how the model can be extended to take account of past transfers.

[12]Foster and Rosenzweig (2001) use a dynamic limited commitment model and study the effects of altruism on income transfer.

to analyse the effects of others' expectation on the critical discount factor.

Models of informal risk sharing in general solve for consumption and transfer allocations by numerical dynamic programming. Instead of directly analysing the transfer, I study the impact of emotions and intrinsic motivations on the critical discount factor that can support risk sharing. We know that informal insurance achieved by households not only depends on their risk aversion but also on their time preferences, i.e. the discount factor. If households have high preference for today, or a lower discount factor, then they will be less likely to make a transfer today. As their patience level increases, or the discount factor approaches 1; perfect risk sharing can be achieved. We may then define the level of informal insurance by the critical discount factor, δ_c, above which risk sharing is self-enforcing. Using this inverse relationship between the critical discount factor and informal insurance, Laczo (2014) defines the level of informal insurance as the reciprocal of δ_c, $1/\delta_c$. I follow the same idea and analyse the effects of envy, altruism and intentions on the critical discount factor and the level of informal insurance.

In section 3, I study the effects of inequity aversion on risk sharing. A household is inequity averse if it dislikes being ahead (altruism) and behind (envy) another household in material consumption. Pure altruism or inequity inversion alone cannot explain a wide range of human behaviour. The repeated nature of interaction and experimental evidence suggest that individuals are conditional cooperators, that is they cooperate only if others do. This reciprocal behaviour is captured by instrumental reciprocity using the traditional infinitely repeated game framework in a static limited commitment model. The history of play matters only in as much as defection and punishments are concerned. After setting up the model in section 3, I show that the set of feasible and individually rational payoffs changes with the intensity of emotions in the risk sharing game. The presence of advantageous disutility changes the set of feasible payoffs in the sense that the end points of the feasible set close in as households become more altruistic. The existence of envy or disadvantageous utility shrinks this set and makes the set of equilibria more equitable. Finally, I show that the critical discount factor that can support informal risk sharing is lower if households have Fehr-Schmidt preferences and the level of informal risk sharing is higher.

In section 4, I change the preference structure to allow for intrinsic reciprocity. Intrinsic reciprocity implies that a kind (unkind) act by one player elicits kindness (unkindness) in response, despite the absence of longer term gains. Intrinsic reciprocity is, therefore, preference based. It relies on the idea that individuals' conception of fairness and perception of actions of others depends on people's intentions.

Therefore, intrinsic reciprocity models are developed within the psychological game theory framework[13]. Given the complex nature of psychological games, I develop a somewhat simplified model that captures both intrinsic and instrumental reciprocity and study how expectations of palyers about actions of other players affect the critical discount factor and the level of insurance in informal risk sharing. In particular, in the stage game, I restrict household's choice to a binary action: either to transfer nothing or to transfer the full risk sharing amount. I show that if people are intrinsically motivated, then in the stage game equilibrium behaviour coincides with the standard pure strategy Nash equilibrium; households do not make any transfer. In the repeated game, however, full risk sharing can be achieved but at a higher discount factor than with the standard selfish preferences. My result implies that in the standard static limited commitment model, intrinsic reciprocity crowds out instrumental reciprocity in the sense that when a household takes into account the fact that the other household is cooperating only because of her selfish interests, then the lower bound on the discount factor that can support full risk sharing increases. The main contribution of the chapter is presented in Proposition 4.4 and Corollary 4.1.

Ideally, intrinsic reciprocity should be history dependent. If households have reciprocity preferences, we would expect their utility to increase in the partner's past kindness. This possibility, however, is left for the future work, see section 5. The rest of the chapter is structured as follows. Section 2 gives a brief overview of theories of reciprocity. Sections 3 and 4 assume Fehr-Schmidt and intrinsic reciprocity preferences, respectively, to solve the model for the critical discount factor and the level of informal insurance. Section 5 describes possible future extensions of the current work. Finally, Section 6 concludes the chapter.

2 Theories of Reciprocity

There are three strands of literature in economics that model reciprocal behaviour in humans. The standard game theoretic approach to modeling reciprocity is embedded in the repeated game framework. Strategies describe the actions of players in every period of the repeated game conditional on the past behaviour of all players. In these models, players have selfish preferences and continue to cooperate with others as long as others cooperate. Any defection is punished according to the equilibrium strategy. Cooperative behaviour is viewed as sacrificing short-term

[13]See Rabin (1993), Dufwenberg and Kirchsteiger (2004) and Battigalli and Dufwenberg (2009). The seminal paper in Psychological Game Theory is Geanakoplos, J. et al. (1989).

gains to benefit in the long run. Players continue to follow the strategy because cooperation induces cooperative behaviour from others in the future. By applying the Folk Theorem, a broad range of behaviour can be supported as equilibria in the repeated game. This kind of behaviour represents instrumental reciprocity (Sobel, 2005).

In contrast to instrumental reciprocity, intrinsic reciprocity views reciprocal behaviour as strictly motivated by preferences. A kind (unkind) action by a player changes the preferences of the other player in a way that elicits kindness (unkindness) in response. As the game unfolds, players constantly update their beliefs and hence preferences. Whether one views others' actions as kind or unkind depends on the perceived intentions of the rival. Thus, the intention behind an action is an important determinant of cooperation or punishment. Unlike instrumental reciprocity, intrinsic reciprocity is backward looking. These models (Rabin 1993; DK, 2004) have been developed within the framework of psychological game theory (Geanakopolos et al. 1989; Battigalli and Dufwenberg, 2009). A player whose preferences reflect intrinsic reciprocity will be willing to sacrifice his own material payoff to increase the material payoff of others in response to kind behaviour while at the same time she will be willing to sacrifice material payoff to decrease rival's material payoff in response to unkind behaviour.

The third class of models of reciprocity is based on static other-regarding preferences, e.g. Fehr and Schmidt (1999), and Bolton and Ockenfels (2000). These theories do not depend on the context or actions of others. Preferences are not updated as the game unfolds but remain fixed. Players' emotional sentiments are captured by fixed parameters. These models are entirely outcome oriented, and ignore the role of intentions or beliefs. Falk and Fischbacher (2006) develop a model of reciprocity that combines intention based reciprocity and other-regarding preferences.

In this chapter, I work with both models of the second and third type. I embed them in a repeated game framework to model strategic\instrumental reciprocity and study informal risk sharing contracts.

3 Social Preferences and Risk Sharing

In this section, I assume that households have Fehr-Schmidt preferences, henceforth FS. To mitigate the risk of uncertain income, such FS households agree on an informal risk-sharing contract, whereby a household with high income will make a transfer to a low income one. I now formally set up the model.

3.1 The Model

There are two infinitely lived households, denoted by i and j. There is a single consumption good, y, in this economy. In every period t, nature draws a pair of endowments. Endowments may take only two values $y_1 = (y^h, y^l)$ or $y_2 = (y^l, y^h)$, where $y^h > y^l$. Household i's endowments are listed first in each case. Both states are equally likely, $\Pr(y_1) = \Pr(y_2) = 1/2$, and states are independent across time. There is no saving or storing mechanism available to households. Preferences of households have two parts, their own material payoffs, $u(c_i)$, and an inequity aversion term. Households evaluate their own consumption by $u(c_i)$. $u(.)$ is a real-valued, strictly increasing, and strictly concave function. Overall utility function of each household is represented by Fehr-Schmidt preferences. For two players, FS preferences are written as:

$$U_i(Y, \alpha, \beta) = u(c_i) - \alpha \max\{u(c_j) - u(c_i), 0\} - \beta \max\{u(c_i) - u(c_j), 0\} \quad (1)$$

where $\alpha \geq 0$, $\beta \in [0, 1)$, and $\beta < \alpha$. If either α or β or both are non-zero, then households have *inequity averse* or *other-regarding preferences*. I assume that both players have the same α and β. Assuming $\alpha = \beta = 0$ gives the standard selfish preferences. There are two features of these preferences that I would like to highlight. First, players' concern about inequity is modelled using one's own material payoff as a reference point to compare others. This implies that households care about how unequal their incomes are, relative to the household that is richer or poorer. This is in contrast with the preference structure in Section 4 where the reference point is a common norm. Second, $\beta < \alpha$ implies that the households care more about disadvantageous inequity than advantageous inequity.

3.2 Game and Strategies

Each period $t = 0, 1, ...$ households play the following stage game, G. After the realization of endowments, both players simultaneously decide a transfer, θ, of consumption good to one another and then consume the net quantities, $c_i = y_i - \theta_i + \theta_j$. There is no formal risk sharing contract between the two households. Hence, in a stage game a standard selfish risk averse household, ($\beta = \alpha = 0$), with higher income would renege on any risk-sharing agreement it may have made ex-ante. A household with FS preferences, in contrast, may or may not fulfil its commitment. Since households are infinitely lived, the stage game is infinitely repeated. In the infinitely repeated game, G_∞, history h^t is defined as a sequence of endowments till period t, including the realization of endowments in period t, and transfers in each previous period, till $t-1$. Let H be the set of all possible histories. A pure strategy for player i is a function $\theta_i : H \rightarrow [0, y_i]$, specifying (a non-negative) amount of transfer by player i after each history. In this section, I only consider the case where players play pure strategies. An informal insurance contract specifies transfer $\Theta = \{\theta_i, \theta_j\}$ in every period t and every history of realized income pairs from one household to another. Transfers must satisfy the feasibility constraint $0 \leq \theta_i \leq y_i$, where y_i is the realized endowment of player i in period t.

3.3 Efficient Allocation

A feasible transfer θ_i is efficient if there exists no other transfer θ_i' that makes both households weakly and at least one household strictly better off. The efficient transfer, denoted by $\overline{\theta}$, is the set of state-contingent transfer which maximizes the average expected utility under commitment. With both the standard and FS preferences, the first best involves full income pooling and then dividing between two households equally in every period, that is perfect risk sharing. This is achieved with a transfer equal to:

$$\overline{\theta} = \frac{y^h - y^l}{2}$$

3.4 Equilibrium

3.4.1 The Stage Game

In an ex-post (after income realization) stage game, players observe their own and their opponents endowments and then unilaterally decide how much to transfer to the other player. The Nash equilibrium of this stage game with selfish preferences is that no player makes any transfer. Under FS preferences, however, the equilibrium behaviour is characterized by the following Lemma. Since both players are ex-ante identical, I drop the individual specific subscripts on material payoffs, and only use them where the distinction is necessary.

Lemma 3.1 *If Player i's income is y^h and player j's income is y^l, then equilibrium transfer is:*

$$\theta_i^* = \begin{cases} \theta = \frac{\Delta y}{2} & if \quad 0.5 \leq \ \beta < 1 \\ 0 < \theta < \frac{\Delta y}{2} & if \quad \frac{u'(y^h)}{u'(y^l)+u'(y^h)} < \beta < 0.5 \\ \theta = 0 & if \quad 0 \leq \beta \leq \frac{u'(y^h)}{u'(y^l)+u'(y^h)} \end{cases}$$

where $\Delta y = y^h - y^l$.

Proof of Lemma 3.1 is given in the appendix, $A-2$. Lemma 3.1 states that if players have FS preferences, then even in the stage game full risk sharing is achievable if households weigh their own payoff atleast as much as the rival's, $\beta \geq 0.5$. Note that if $\beta > 0.5$, then we have a corner solution, $\theta^* = \frac{\Delta y}{2}$. Household i will never make any transfer greater than $\frac{\Delta y}{2}$ because then i's income will be less than j and the envy part of prefrences will activate. However, it is important to highlight that Fehr and Schmidt $(1999$, table $III)$ suggests that about 40% of subjects have $\beta \geq 0.5$. Similarly, Charness and Rabin $(2002$, table $VI)$ suggest that a sizable minority of subjects satisfies $\beta \geq 0.5$. If $\frac{u'(y^h)}{u'(y^l)+u'(y^h)} < \beta < 0.5$, then partial risk sharing is implemented. For all values of $\beta \leq \frac{u'(y^h)}{u'(y^l)+u'(y^h)}$, no transfer will be made by a lucky household. Unlucky household j will not make any transfer, it suffers from envy.

I now provide an example with isoelastic utility function with the coefficient of relative risk aversion equal to 1, $u(.) = \ln(.)$.

Example 3.1 *Suppose that both household have* $\ln$ *utility function as their material payoffs and household* i *has the higher income. Then,* i*'s utility function is*

$$U_i(y^l, y^h, \beta) = \ln u(y^h - \theta) - \beta[\ln(y^h - \theta) - \ln(y^l + \theta)]$$

The derivative with respect to θ *is*

$$\frac{\partial\left(U_i(.)\right)}{\partial\theta} = -\frac{1}{y^h - \theta} - \beta[-\frac{1}{y^h - \theta} - \frac{1}{y^l + \theta}]$$

The optimal transfer will be giveb by

$$\begin{array}{lll} \theta^* = 0 & if & 0 \leq \beta \leq 0.2 \\ \theta^* = \beta(y^h + y^l) - y^l & if & 0.2 < \beta < 0.5 \\ \theta^* = \frac{(y^h + y^l)}{2} & if & 0.5 \leq \beta < 1 \end{array}$$

Now suppose that i*'s income is* $y^h = 8$ *and* B*'s income is* $y^l = 2$*. Full risk sharing,* $(\theta^* = 3)$*, is achieved when* $\beta \geq 0.5$*. When* $0 \leq \beta \leq 0.2$ *the optimal transfer is zero,* $\theta^* = 0$*. Finally, if* $0.2 < \beta < 0.5$*, then there will be imperfect risk sharing,* $0 < \theta^* < 3$*.*

3.4.2 The Repeated Game

To model instrumental reciprocity, I now assume that the stage game is played infinitely. Since there is no formal risk sharing agreement between households, the informal risk sharing contract must be self-enforcing. In particular, I assume that households agree to follow grim trigger strategy. That is, households agree to participate in the risk sharing mechanism and continue to cooperate as long as the other does, but revert to the state contingent Nash equilibrium of the stage game if the lucky household reneges. For the repeated game in this section, the equilibrium concept I use is subgame perfect equilibrium.

Static Nash equilibria can be divided into two categories. For $\beta \leq \frac{u'(y^h)}{u'(y^h)+u'(y^l)}$, households live under autarky. For higher value of β some risk sharing will be provided. Assume that $0 < \beta \leq \frac{u'(y^h)}{u'(y^h)+u'(y^l)}$. Then, when households revert to Nash equilibrium they do not make any transfers. In this case, both households consume their endowments forever. The minmax payoff for each household is given by:

$$\underline{v}^s = \tfrac{1}{2}\left(u(y^h) + u(y^l)\right) \quad if \quad \beta = \alpha = 0 \tag{2}$$

$$\underline{v}^{FS} = \frac{1}{2}\left(u(y^h) + u(y^l)\right) - \alpha\frac{1}{2}\left(u(y^h) - u(y^l)\right) - \beta\frac{1}{2}\left(u(y^h) - u(y^l)\right) \tag{3}$$

Minmax payoffs are the same for both households. Expression (2) is the minmax payoff when households have standard selfish preferences and (3) with FS preferences. We can easily see that $\underline{v}^{FS} < \underline{v}^s$.

3.4.3 Feasible and Individually Rational Payoffs

I now analyse how FS preferences change the set of feasible and individually rational payoffs for an infinitely repeated risk sharing game as compared to standard preferences. Figure $2a$ below shows the set of feasible payoffs with standard preferences: the shaded region is the feasible and individually rational set. $\underline{v}^s$ is the state contingent autarky payoff (2) when $\alpha = \beta = 0$. Figure $2b$ shows how the feasible set changes as players' concerns for fairness becomes positive, $\alpha > 0,\ \beta > 0$. First, let us consider the case when both households share the risk completely and consume equal amount, $\overline{y}$. Then, under both standard and FS preferences, the feasible point remains the same, point z is achieved in figure $2b$. The envy and altruism parts of FS preferences vanish. As household i's income increases relative to j, the boundary of the feasible set below z pivots inwards because i suffers disutility from inequity. However, j suffers more disutility than i as $\alpha > \beta$. Therefore, the inwards movement above z will be greater than below z. Similarly, when j's income is higher than i, the boundary pivots inwards from the top and the bottom but the inwards movement will be higher below z than above z. This implies that the boundary of the feasible set will be defined by β. Second, as is obvious from expression (2) and (3), $\underline{v}^{FS} < \underline{v}^s$. Keeping α constant, an increase in β implies that the feasible set shrinks inwards and the minmax payoff decreases. Any increase in α will also

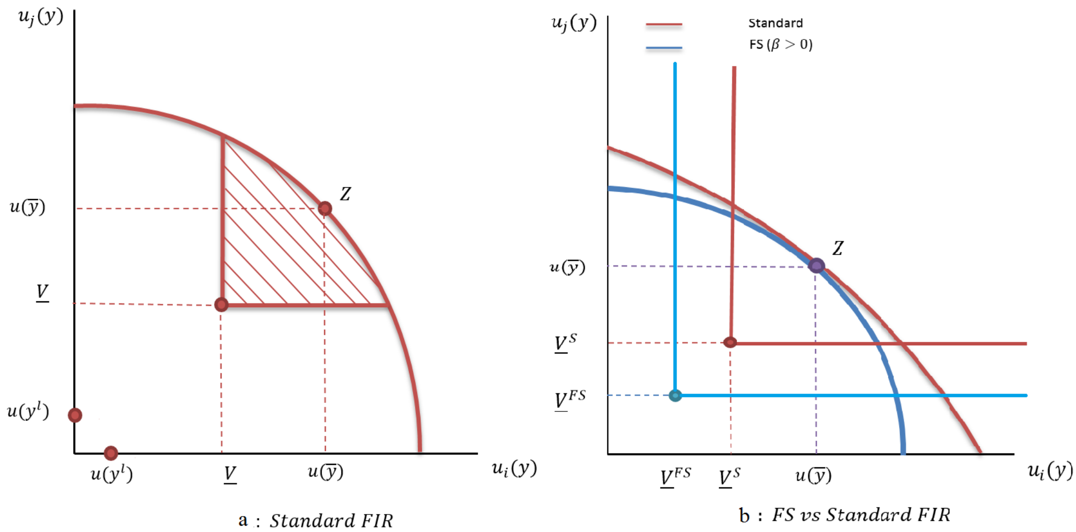

Figure 2: Standard vs FS FIR

decrease $\underline{v}^{FS}$, but α will not affect the boundary; instead it changes the individually rational set.

3.4.4 Equilibrium and the Level of Risk Sharing

I now turn to the equilibrium of the infinitely repeated game. I shall show that there exist a critical discount factor, δ_c^{FS}, such that, $\forall\ \delta \geq \delta_c^{FS}$, informal risk sharing is self-enforcing. I then compare this critical discount factor with the one obtained under selfish preferences.

Since households are assumed ex-ante identical, they have the same preferences and incomes are generated from the same process; we do not need to specify constraints, transfers and discount factors separately for each player. Consider any period t, the expected lifetime utility of a lucky household in autarky after defection from the trigger strategy in period t is given by

$$\underbrace{u(y^h) - \beta\left(u(y^h) - u(y^l)\right)}_{Period\ t\ utility\ without\ making\ any\ transfer} + \underbrace{\frac{\delta}{1-\delta}}_{After\ period\ t\ utility}\underline{v}^{FS}$$

The expected lifetime utility of a lucky household if it continues to participate in the risk-sharing, instead of defecting, is given by

$$\underbrace{u(y^h - \theta) - \beta\left(u(y^h - \theta) - u(y^l + \theta)\right)}_{Period\ t\ utility\ with\ transfer} + \underbrace{\frac{\delta}{1-\delta}v(\Theta)}_{After\ period\ t\ utility}$$

where

$$\begin{aligned} v(\Theta) &= \frac{1}{2}\left(u(y^h-\theta)+u(y^l+\theta)\right)-\alpha\frac{1}{2}\left(u(y^h-\theta)-u(y^l+\theta)\right) \\ &\quad -\beta\frac{1}{2}\left(u(y^h-\theta)-u(y^l+\theta)\right) \end{aligned}$$

I now find the lowest possible discount factor such that risking sharing becomes self-enforcing. Risk sharing is self-enforcing if the gain from defection is smaller than the value of continued participation. This can be represented by the following incentive constraint:

$$u(y^h)-\beta\left(u(y^h)-u(y^l)\right)+\frac{\delta}{1-\delta}\underline{v}^{FS} \leq u(y^h-\theta)-\beta[u(y^h-\theta)-u(y^l+\theta)]+\frac{\delta}{1-\delta}v(\Theta) \tag{4}$$

Rearranging (4) gives us the critical discount factor that can support risk-sharing.

Proposition 3.1 *If households have FS preferences, then the critical discount factor that can support risk sharing is given by*

$$\delta_c^{FS}(\beta,\alpha)=\frac{u(y^h)-\beta\left(u(y^h)-u(y^l)\right)-u(y^h-\theta)+\beta\left(u(y^h-\theta)-u(y^l+\theta)\right)}{\begin{pmatrix} u(y^h)-\beta\left(u(y^h)-u(y^l)\right)-u(y^h-\theta) \\ +\beta\left(u(y^h-\theta)-u(y^l+\theta)\right)+v(\Theta)-\underline{v}^{FS}\end{pmatrix}}$$

for $0 \leq \beta \leq \frac{u'(y^h)}{u'(y^l)+u'(y^h)}$.

For all $\delta \geq \delta_c^{FS}(\beta,\alpha)$ some risk sharing can be self-sustained. After substituting the expression for $v(\Theta)$ and $\underline{v}^{FS}$, δ_c^{FS} can be written as

$$\delta_c^{FS}(\beta,\alpha)=\frac{u(y^h)-u(y^h-\theta)-\beta\left(\left(u(y^h)-u(y^l)\right)-\left(u(y^h-\theta)-u(y^l+\theta)\right)\right)}{\frac{1}{2}\left(1-\beta+\alpha\right)\left(u(y^h)-u(y^l)-\left(u(y^h-\theta)-u(y^l+\theta)\right)\right)} \tag{5}$$

Proposition 3.2 below describes the relationship between $\delta_c^{FS}(\beta,\alpha)$, the fairness parameters, α and β, and selfish preferences.

Proposition 3.2 $\delta_c^{FS}(\beta,\alpha)$ *is decreasing in both* α *and* β*, and the critical discount factor that can sustain informal risk sharing for households with FS preferences is smaller than households with selfish preferences.* $\delta_c^{FS} < \delta_c^{S}$.

Proof of Proposition 3.2 is provided in the appendix, A-2. Proposition 3.2 states that the critical discount factor reduces as envy and altruism parameters increase. An increase in any of the two fairness parameters makes it easier to satisfy the incentive constraint (4). The intuition behind this is that a higher value of β makes both defection in period t and the punishment in period t onwards more costly for FS household while participation reduces disutility from inequality. Hence, the gain from defection decreases as β increases. Similarly, with a higher α households suffer more from envy when they are unlucky, and the lucky household makes no transfer as punishment is implemented. The second part of the Proposition states that the critical discount factor required to support risk sharing is lower with fairness concerns. As $\alpha \to 0$ in expression (5), the critical discount factor coincides with the standard preferences. Note that $\alpha \geq \beta$, when α approaches zero, β also goes to 0. Hence, positive values of α and β serve as instruments to support more egalitarian cooperation even under lower patience level. Fafchamps (2003) makes a similar argument, in his Proposition 4.2, that as the patience level decreases, the gain from risk sharing must be shared more equally. He further argues that as δ goes down, risk sharing becomes harder to achieve, because all participants insist on equal distribution. Proposition 3.2 provides the underlying rationale behind the relationship between the lower level of δ and more equitable distribution of payoff. However, in contrast to Fafchamps (2003), our results have a different interpretation: risk sharing can be supported at the lower discount factor because individuals have inequity concerns. Envy and altruism both help achieve more equitable distribution at a lower discount factor.

Substituting $\theta = \frac{\Delta y}{2}$ in expression (5) gives the critical discount factor to support full risk sharing, $\delta^{FS}_{cfs}(\beta, \alpha)$. Suppose that $\delta^{FS}(\beta, \alpha)$ falls short of $\delta^{FS}_{cfs}(\beta, \alpha)$, so complete risk sharing is not achievable. If $\delta^{FS}(\beta, \alpha)$ is sufficiently large (but smaller than $\delta^{FS}_{cfs}(\beta, \alpha)$), then we can still support partial risk sharing. Take the derivative of the right hand side of the expression (5) with respect to θ. The sign of the derivative is determined by:

$$\frac{1}{2}(1-\beta+\alpha)\left(u'\left(y^h-\theta\right)\left(u\left(y^l+\theta\right)-u\left(y^l\right)\right)+u'\left(y^l+\theta\right)\left(u\left(y^h-\theta\right)-u\left(y^h\right)\right)\right)$$

which can be negative or positive. Evaluating the derivative at $\theta = \frac{\Delta y}{2}$, full risk sharing, gives:

$$\frac{1}{2}(1-\beta+\alpha)\left(u'(1/2)\left(u(1/2)-u\left(y^l\right)\right)+u'(1/2)\left(u(1/2)-u\left(y^h\right)\right)\right)>0$$

Hence, reducing θ below $\theta = \frac{\Delta y}{2}$ (say to $\widehat{\theta}$) decreases the bound on values of $\delta^{FS}_{c}(\beta, \alpha)$ for which the incentive constraint can be satisfied. This suggests that there are values of the discount factor that will only support stationary equilibria with partial insurance. This value, $\widehat{\theta}$, describes the efficient, symmetric and stationary equilibrium for a given discount factor, in which consumption is

$\left(y^h - \widehat{\theta},\ y^l + \widehat{\theta}\right)$ in state y_1 and $\left(y^l + \widehat{\theta},\ y^h - \widehat{\theta}\right)$ in state y_2. There will also be a host of other equilibria with stationary outcomes with symmetric and asymmetric payoffs.

Note that a lower critical discount factor means that more informal insurance will be achieved. Hence, the level of insurance can be defined as the reciprocal of the critical discount factor, $\frac{1}{\delta_c}$, as in Laczo (2014). I now define the level of insurance as:

Definition 3.1 *The level of informal insurance is defined as the reciprocal of critical discount factor:*

$$\frac{1}{\delta_c^{FS}} = 1 + \frac{v(\Theta) - \underline{v}^{FS}}{u(y^h) - \beta\left(u(y^h) - u(y^l)\right) - \left(u(y^h - \theta) - \beta\left(u(y^h - \theta) - u(y^l + \theta)\right)\right)}$$

The level of informal insurance has a natural interpretation: the level of insurance depends on the expected future gains relative to autarky (numerator) and today's cost of fulfilling the obligation (denominator) of sharing risk contract. Proposition 3.2 together with Definition 1 gives us the following corollary.

Corollary 3.1 *The level of informal insurance is higher under FS preferences as compared to the selfish preferences. The level of insurance increases with increase in* α *and* β*.*

Proof. Immediate consequence of Proposition 3.2 and Definition 1. ■

In the next section, I look at a preference structure that captures intention based reciprocity.

4 Intrinsic Reciprocity and Risk Sharing

I now consider another class of other-regarding preferences that captures intrinsic reciprocity or belief based reciprocity. The literature on intrinsic reciprocity is relatively new and to my knowledge, there is no existing theoretical analysis of the interaction between instrumental and intrinsic reciprocity[14].

To motivate the basic idea of intrinsic reciprocity, let us consider a simple two-period risk sharing game. Suppose that there are two households as before and they have agreed to form an informal full risk-sharing contract. Nature draws two income pairs; $(y_i = 10,\ y_j = 5)$ in the first period and $(y_i = 5, y_j = 20)$ in the second

[14]Cabral et al. (2015) experimentally study the veto game to disentangle altruism, intrinsic and instrumental reciprocity.

period. In the first period, household i is lucky and thus, it is expected to make a transfer to j, while in the second period, j is lucky and should make a transfer to i. Each household has two options; either to transfer nothing, $\theta = 0$, or to make a full risk sharing transfer $\theta = \frac{\Delta y}{2}$. In the first period, if i decides to make the transfer, then both households get (7.5,7.5) and if it makes no transfer, then i consumes 10 while j gets 5. i makes the decision without knowing whether j will reciprocate in the next period. In the second period, j has the higher income and decides on the transfer. Intrinsic motivations imply that j will only make a transfer if i had made a transfer in the first stage. In other words, j fulfils its obligation only if i did too in the previous period. If i had reneged on the contract, then j will not transfer and both households will consume their endowments in the second period.

From the standard game theory, we know that the subgame perfect equilibrium of this two-period game is that both players transfer nothing. Now let us suppose that j has FS preferences, as in section 3, whereas i is selfish. Furthermore, assume that i fulfilled its commitment and made a transfer in the first period. Given the FS preference structure, j's utility in the second period reduces to $U(.) = 20 - \beta[20 - 5]$ if j transfers nothing and $U(.) = 12.5$ if it fulfils the contract. For $\beta \in (\frac{1}{2}, 1]$, j makes a transfer, $\theta_j = \frac{\Delta y}{2} = 7.5$, and both players end up consuming 12.5 in the second period. However, FS preferences do not account for people's intentions in the sense that if i chose to transfer, then can we claim that it has been kind to j? We cannot be certain; suppose that i believes that j is most likely choose to transfer if i transfers in the first stage. Thus, by transferring in the first period, i is just maximizing its own payoff since i gets 12.5 if j transfers and 5 if j does not transfer. Therefore, we can infer that i is kind to j the less it believes that j will make a transfer in the second stage. While deciding at the second stage, j with FS preferences, cannot take account of i's intentions. j makes the transfer entirely based on the intensity of its altruistic feelings, β, and does not take account of i's intention. If i chooses not to transfer, then obviously it is not kind towards j. Hence, the lower the probability i assigns to $\theta_j = \frac{\Delta y}{2}$, the more it is deemed to be kind after $\theta_i = \frac{\Delta y}{2}$. It is these beliefs-based motivations that I intend to capture in this section. As mentioned in the introduction, intention-based reciprocity is modelled with a psychological game theoretic framework, therefore in this section, I change the preference structure of our model.

In the standard game theoretic setup, players do not directly derive utility or disutility from their beliefs about others (own first-order beliefs), or beliefs of others (others' first order beliefs) or beliefs about the beliefs of others (own second order beliefs), and so on. The example above shows that j's emotions and actions may change if it considers i's intentions. Since these beliefs are endogenously determined, we cannot simply add psychological payoffs to the material payoffs and use the framework of classical game theory. Psychological games are different from standard games in the sense that in addition to strategies, players' payoffs also depend on players' beliefs about others' strategies and/or beliefs. In other words, payoffs are belief dependent. A new theoretical structure has been developed by Geanakoplos, Pearce and Stacchetti (1989; henceforth GPS) and later generalized by Battigalli and Dufwenberg (2009). Building on GPS, Rabin (1993) first developed a theory of reciprocity which was then generalized to dynamic games by DK (2004).

The fundamental idea behind intrinsic reciprocity is that a household would like to be kind (unkind) in response to kind (unkind) behaviour from the other household. I now briefly elaborate on what it means to be kind. Suppose that household i chooses an action, θ_i, and forms beliefs about j's actions, i's first order beliefs are denoted by α_i. Given these beliefs, i then chooses an action in such a way that it gives a certain material payoff to j, $u_j(\theta_i, \alpha_i)$. How kind i is to j depends on the relative size of $u_j(\theta_i, \alpha_i)$ within the set of feasible payoffs of j. The particular form of kindness depends on the context, but all measures are relative to some reference point. Both Rabin (1993) and DK (2004) define this reference point to be the equitable payoff, i.e. the average between the highest and the lowest material payoffs of j given that i chooses an efficient strategy. If i's action gives j a payoff above (below) this reference point, then i is referred kind (unkind). If j's payoff is exactly equal to the equitable payoff, then i has been neither kind nor unkind. To reciprocate others' actions, players make inference about others' kindness, and perceived kindness, and then decide to act in a kind or unkind way. Making an inference about others' kindness involves players' second-order beliefs. In addition to strategies, players' utilities then become a function of beliefs.

Given the complex nature of psychological games, I simplify the risk sharing game in this section. I restrict the choice set of players to two actions: no transfer or transfer the full risk sharing amount. Since my focus is on how beliefs and intentions interact with instrumental reciprocity and determine the level of risk sharing these simplifications do not compromise the analysis. I continue to work with the static limited commitment model; this implies that I stick to stationary strategies, so that past kindness does not affect any period's decision. In section 5, I shall suggest that taking account of past kindness is a part of future research agenda, and I propose a way to capture it in these kinds of models. Since kindness depends on the context, below I define perceived kindness and kindness according to the risk sharing game. I set up the model again as strategies and the interpretation of strategies change.

4.1 The Model

There are two infinitely lived households and I refer to them as i and j. Households agree on an informal risk sharing contract. There is a single consumption good, y. Endowments take only two values $y_1 = (y^h, y^l)$ or $y_2 = (y^l, y^h)$. Household i's endowments are listed first in each case. Nature draws a pair of endowments each time period t. Each state is equally likely, $\Pr(y_1) = \Pr(y_2) = 1/2$. In the stage game, G, each household has two pure actions, $\Theta_i = [\theta^n = 0, \theta^s = \frac{\Delta y}{2}]$. Player i can either transfer zero or full risk sharing amount. After the realization of endowments in every period, households simultaneously choose their actions. In the infinitely repeated game, G_∞, the stage game is played in each period $t \in \{0, 1, 2, ...\}$. History, h^t, is defined as a sequence of endowments till period t, it includes the realization of endowments in period t, and transfers in each previous period, till $t-1$. Let H be the set of all possible histories. A behavioral strategy, Σ_i, is defined as a probability distribution over the set of pure strategies, $\Delta\Theta_i$, at every ex-post history h. Let $\sigma_i \in \Sigma_i$ be the probability that player i assigns to θ^s at history h. Moreover, let $\Sigma = (\Sigma_i, \Sigma_j)$. Once households have chosen their actions, they consume the resulting net quantities of the consumption good. Full risk sharing implies that both households consume $\overline{y} = \frac{y^h + y^l}{2}$, and no transfer implies autarky consumption. Feasibility of transfer is always satisfied.

4.1.1 Preferences

Households' utility function again consists of two terms which now are their own material payoff as before and the reciprocity payoff that captures intrinsic reciprocity. As before $u_i(.)$ represents the material payoff of player i. $u_i(.) : \Sigma \rightarrow R$ is a strictly increasing and strictly concave function. The reciprocity payoff depends on others' beliefs about i's actions, j's first-order beliefs, and the other's material payoffs, $u_j(.)$. Let B_{ij} be a set of first order beliefs of i about j's actions and $B_{ij} = \Sigma_j$, B_{ji} is similarly defined. Let $B = (B_{ij}, B_{ji})$. Since we have only two actions for each player, I represent first order beliefs as follows. α_i is the belief that player i has about j that j will transfer $\theta^s = \frac{\Delta y}{2}$ and $(1-\alpha_i)$ is the belief that j will transfer $\theta^n = 0$. Hence, from our construction $\alpha_i = \sigma_j$. Player i's overall utility function can be defined as:

Definition 4.1 *Player i's utility function at any given history is a function*

$$U_i(.) : \Sigma \times B_{ji} \times u_j \rightarrow R$$

defined as

$$U_i(\sigma_i, \alpha_j, u_j) = u_i(y_i, \sigma_i) + \eta K_{ji} u_j(y_j, \sigma_i) \tag{6}$$

where η is a non-negative number, K_{ji} is household j's kindness towards i and is a function of j's first order beliefs. K_{ji} is defined below.

The reciprocity component of preferences is captured by the term $\eta K_{ji} u_j(y_j, \sigma_i)$. Here, η measures each household's sensitivity to reciprocity towards the other household and takes on values in the interval $[0, b]$, where b is some large number. Both players are assumed to have the same reciprocity sensitivity which is common knowledge. When $\eta = 0$, we have standard preferences. K_{ji} is j's kindness towards i. If household j is kind to i, then $K_{ji} > 0$ and i views j positively. In this case, i may sacrifice its own payoff to increase j's material payoff and an increase in j's material payoff increases i's overall utility. If $K_{ji} < 0$ then j's material payoff enters negatively in the utility function and gives i disutility.

I now define the kindness of j towards i, K_{ji}. K_{ij} is similarly defined. To define kindness (and perceived kindness), the reciprocity literature uses a reference point, called the equitable payoff, with respect to which households judge their own and others' action. DK (2004) define equitable payoff as follows:

"*j will neither be kind nor unkind if j believes that i's material payoff will be the average between the highest and the lowest payoff of i that is compatible with j choosing an efficient strategy.*"

For our purpose, I first define this reference point in terms of transfer instead of payoffs and call it a fair transfer level. DK (2004) stress that when computing the lowest payoff, one should restrict attention only to efficient strategies. In my case, both strategies are efficient. Households use this fair transfer level to judge others' behaviour.

Definition 4.2 *A fair transfer level at history t is the average between the highest and the lowest feasible transfer.*

$$\theta^f = \frac{\Delta y/2 + 0}{2} = \frac{\Delta y}{4}$$

Think of θ^f as a fairness norm for a given pair of realized incomes. It is an average of the highest and the lowest transfer a high-income household can give to the low-income household. More generally, one could consider any convex combination of two transfers as a fair transfer level. Note that θ^f is independent of any beliefs and that once the income pair is realized, θ^f is commonly known.

The immediate consequence of this definition is that the full risk sharing transfer, $\theta^s = \Delta y/2$, is considered to be kind and $\theta^n = 0$ unkind. In my two state game, θ^f will be a constant and equal to $\frac{\Delta y}{4}$, but in case of more states, each realization of income will have a unique fair transfer level. If both households have the same income, then $\theta^f = 0$, as there will be no income difference. Here, I stick to a two-state case and make the following assumption about θ^f.

Assumption 1 The fair transfer level is 0 for the low-income household and $\frac{\Delta y}{4}$ for the high-income household.

Assumption 1 implies that when high-income household decides how much to transfer, it knows that the fair transfer level expected of him is $\theta^f = \frac{\Delta y}{4}$, while the low-income household knows that the fair transfer expected from him is zero. This gives us a desirable feature of kindness in the context of risk sharing game. If a household is unlucky, then the norm does not require the unlucky household to make a transfer. Moreover, when the unlucky household does not make a transfer, this is not considered unkind. Of course, any positive transfer from an unlucky household will be considered kind. Now this begs a question that if i's income is high, then how can j be kind or unkind to i given that j is not supposed to make a transfer under the insurance contract? In other words, when i's income is high, then according to the informal contract, j is passive in the sense that it is not required to make any transfer. Instead, j expects a transfer from i. While j is at the receiving end, it makes expectations about i's transfer. How much j expects from i defines j's kindness towards i. From j's point of view, the expected transfer from i, θ^e is:

$$\theta^e = 0(1-\alpha_j) + \frac{\Delta y}{2}\alpha_j = \frac{\Delta y}{2}\alpha_j$$

Kindness of j towards i is the difference between the fair transfer level and the expected transfer. Following Rabin (1993), I normalize the kindness function by dividing it by the difference between the highest and the lowest transfer, $\frac{\Delta y}{2}$.

Definition 4.3 *The kindness of household j towards i is given by*

$$\begin{aligned} K_{ji}(\alpha_j) &= \frac{\theta^f - \frac{\Delta y}{2}\alpha_j}{\frac{\Delta y}{2}} = \frac{1}{2} - \alpha_j \quad if\ y_1 = (y_i^h, y_j^l)\ is\ realized \\ K_{ji}(\alpha_j) &= \frac{0 - \frac{\Delta y}{2}\alpha_j}{\frac{\Delta y}{2}} = -\alpha_j \qquad if\ y_2 = (y_i^l, y_j^h)\ is\ realized \end{aligned} \tag{7}$$

Intuitively, the above definition of kindness reflects the idea that j's kindness towards i depends on j's expectation about i's transfer. If j's income is low, then any $\alpha_j > \frac{1}{2}$ makes j unkind towards i and vice versa. If $\alpha_j = \frac{1}{2}$, then j is neither kind nor unkind and the reciprocity payoff vanishes. When j's income is low, the range of K_{ji} is given by: $K_{ji} \in [-\frac{1}{2}, \frac{1}{2}]$. The second line of the expression (7) says that if j's income is high, then the fair transfer from i is 0 (by assumption) and if j assigns any positive probability to $\theta^s = \frac{\Delta y}{2}$, then j is unkind to i[15]. In this case, the range of K_{ji} is: $K_{ji} \in [-1, 0]$.

I now briefly comment on how my preference structure differs from DK (2004) and Rabin (1993). In both papers, kindness towards the other player is a function of players' first-order beliefs. Similarly, they define perceived kindness as a function of first and second order beliefs. The basic idea behind perceived kindness is that to reciprocate; a player needs to make an inference whether the others have been kind to her or not. However, a player cannot directly observe others' beliefs and hence others' kindness towards her. Therefore, players must make beliefs about others' actions and beliefs; that is, both first and second order beliefs now matter. In a two players case, the utility function is given by

$$U_i(\sigma_i, \alpha_i, \beta_i) = u_i(.) + \eta K_{ij}(\sigma_i, \alpha_i) K_{iji}(\alpha_i, \beta_i) \tag{8}$$

where, $u_i(.)$ is player i's material payoff, η is the sensitivity parameter, σ_i represents i's behavioural strategy, α_i is i's first order beliefs and β_i is i's second-order beliefs. K_{ij} is i's kindness towards j (which is a function of action and first order beliefs of i) and K_{iji} is how j's kindness towards i is perceived by i (which is a function of first and second-order beliefs of i). Note that mathematically $K_{iji} = K_{ji}$, since i's first-order beliefs are equal to j's strategies and i's second-order beliefs are equal to j's first-order beliefs about i's strategies. It is often convenient to use K_{ji}, instead of K_{iji}. If i believes that j has been kind to him ($K_{iji} > 0$), then i's reciprocity payoff is increasing in i's kindness, K_{ij}, to j. Both Rabin (1993) and DK (2004) define kindness and perceived kindness with reference to the equitable payoff. If i's action gives j a payoff above (below) the equitable payoff then i is considered to be kind (unkind).

If one compares the preference structure in (6) with DK's preferences in (8), then one can see two differences. First, I have replaced $K_{ij}(\sigma_i, \alpha_i)$ from (8) with j's

[15]Even if we keep the fair transfer level same, $\theta^f = \frac{\Delta y}{4}$, the equilibrium behaviour will not change. I think that assigning any probability that the opponent will make a transfer when opponent's income is low should be considered unkind, especially when players have an informal risk sharing contract.

material payoff $u_j(.)$. In my formulation, i acting kindly or unkindly directly determines j's payoff without any comparison against equitable payoff or fair transfer level. For my purpose, it is convenient to work with payoffs because at any given history only one household will be making a transfer and it only needs to consider the other player's beliefs, not the other's actions. A similar approach has been taken by Battigalli (2007) and Attanasi et al.(2015). Secondly, I have replaced $K_{iji}(\alpha_i, \beta_i)$ with $K_{ji}(\alpha_j)$ in expression (6). As mentioned above, these two expressions are mathematically equivalent, and it is easier to work with lower order beliefs. I will be working with the other player's first order beliefs instead of their own second-order beliefs. Moreover, note that, in equilibrium the first-order beliefs of j have to match with the second-order beliefs of i. This formulation is consistent with the psychological game theory framework developed in Battigalli and Dufwenberg (2009). Finally, players' time preferences are captured by a discount factor δ.

4.2 Equilibrium

4.2.1 The Stage Game

I now define the equilibrium for the stage game.

Definition 4.4 *A reciprocity Nash equilibrium of the stage game is a pair* (σ^*, B^*) *such that for* i*,* $i \neq j$*,*

$$\begin{aligned} \sigma_i^* &\in \arg\max_{\sigma_i \in \Sigma_i} U_i(\sigma_i, B_{ji}, u_j) = \arg\max_{\sigma_i \in \Sigma_i} u_i(\sigma_i, \alpha_j) + \eta K_{ji} u_j(\sigma_i, \alpha_j) \\ \alpha_j &= \sigma_i^* \end{aligned}$$

From Geanakoplos et al.(1989), we know that if players have psychological preferences as defined here, then the equilibrium exists. Reciprocity Nash equilibrium is simply the Nash equilibrium with an additional condition that beliefs match the actual action. In this subsection, I solve the ex-post stage game for any positive value of η. Proposition 4.1 below states that the only pure strategy equilibrium in the stage game is that both households choose not to transfer any amount to the other, and the other household should not expect any transfer.

Proposition 4.1 *The only pure strategy reciprocity Nash equilibrium of the stage game is* $\sigma_i^* = \sigma_j^* = 0$ *and* $\alpha_j = \alpha_i = 0$ *for* $\eta \in (0, 2M)$*. Where*

$$M = \frac{u(y^h) - u(\overline{y})}{u\left(\overline{y}\right) - u(y^l)}$$

Proof. Household i with a higher realized income will choose the strategy that gives it a higher payoff. We know from (7) that kindness of j towards i is given by $K_{ji} = \frac{1}{2} - \alpha_j$. Since both players have the same $u(.)$, I drop the subscripts.

[1] Utility from choosing full risk sharing, θ^s(or $\sigma_i = 1$), is: $u(\overline{y}) + \eta(\frac{1}{2} - \alpha_j)u(\overline{y})$ and utility from choosing θ^n (or $\sigma_i = 0$)is: $u(y^h) + \eta(\frac{1}{2} - \alpha_j)u(y^l)$. Full risk sharing, θ^s, gives higher utility than θ^n iff:

$$u(\overline{y}) + \eta(\frac{1}{2} - \alpha_j)u(\overline{y}) \geq u(y^h) + \eta(\frac{1}{2} - \alpha_j)u(y^l)$$

which can be rewritten as

$$\eta(\frac{1}{2} - \alpha_j) \geq \frac{u(y^h) - u(\overline{y})}{u\left(\overline{y}\right) - u(y^l)} \tag{9}$$

Let us denote the right hand side of the expression (9) by M. Since $u(.)$ is strictly concave, we know that $0 < M < 1$. Inequality in (9) can be rewritten as

$$\eta(\frac{1}{2} - \alpha_j) \geq M \tag{10}$$

In equilibrium, α_j has to match with the actual choices of household i. For equation (10) to be satisfied, α_j has to be less than $\frac{1}{2}$ because both M and η are positive. Hence in equilibrium, household i choosing full risk sharing and $\alpha_j = 1$ cannot be an equilibrium.

[2] No risk sharing, θ^n, will be chosen iff:

$$\eta(\frac{1}{2} - \alpha_j) \leq M \tag{11}$$

For no risk sharing to be equilibrium α_j has to be 0. If $\alpha_j = 0$, then the condition (11) is satisfied when $\eta \leq 2M$. For any value of $\alpha_j > 0$, beliefs will not coincide with the action. The condition (11) can be written as $\alpha_j \geq \frac{1}{2} - \frac{M}{\eta}$ and for $\eta > 2M$, α_j will be strictly positive.

[3] For completeness I consider player j's choices as well. Since i's income is higher that j, i's kindness is given by $K_{ij} = -\alpha_i$. The utility of household j with lower income is given by

$$u(y^l - \theta_j) - \eta\alpha_i u(y^h + \theta_j)$$

where $y^l - \theta_j$ is j's net consumption after choosing action θ_j. Hence j's utility is maximized if it transfers nothing, $\theta_j^n = 0$ (or $\sigma_j = 0$), and the only consistent belief for i is $\alpha_i = 0$. ■

Player i's equilibrium action coincides with the standard (pure) Nash equilibrium action. In this psychological risk sharing game, there is also a mixed (behavioral) strategy equilibrium. For households to be indifferent between the two strategies, we must have $\eta(\frac{1}{2} - \alpha_j) = M$, which implies that for any $\eta > 2M$, $\sigma_i^* = \alpha_j^* \in (0, 1/2)$ that satisfies $\frac{1}{2} - \frac{M}{\eta} = \alpha_j^*$ constitutes an equilibrium. To have a consistent comparison with the selfish preferences, I do not use mixed strategy equilibria for the punishment in the repeated game below.

Before moving to the repeated game, I would like to remark that the equilibrium behaviour in reciprocity theories often depends on how one models kindness and perceived kindness. My formulation is inspired by Rabin's definition of kindness, nevertheless, it is different. Both full risk sharing and no risk sharing could be the equilibria if one adopts DK (2004) definition.

4.2.2 The Repeated Game

Since full risk sharing is not achieved in the stage game, I now consider whether things can improve in a repeated game. To support the cooperative behaviour, I turn to the traditional economic incentives, instrumental reciprocity. Players share risk with each other because sacrificing short term gains bring benefit in the long run. First, I define the equilibrium for the repeated game.

Definition 4.5 *A sequential reciprocity equilibrium (SRE) is a (σ, B) at each history $h \in H$ such that,*

$$
\begin{aligned}
\sigma_i^*(h) &\in \arg\max_{\sigma_i \in \Sigma_i(h)} U_i(\sigma_i, B_{ji}(h), u_j(h)) \\
\sigma_i^*(h) &= \alpha_j(h)
\end{aligned}
$$

The definition of SRE states that it is a strategy pair such that at each history h, each household chooses a strategy that maximizes its utility given the other household's beliefs. The second condition states that the beliefs of household j must match the actual actions of household i at every history. At the initial period, the second condition guarantees that the initial beliefs are correct. In any other period, households update their beliefs and assign probability one to the sequences of past choices that lead to history h, and otherwise, the initial beliefs prevail. As household j updates its beliefs, player i's utility also gets updated. This definition is similar to DK (2004) and is equivalent to psychological sequential equilibrium by Battigalli and Dufwenberg (2009) if we truncate belief hierarchy at the first-order beliefs. DK's sequential reciprocity equilibrium involves players' first and second order beliefs.

Before I analyse the repeated game with reciprocity preferences, Proposition 4.2 below gives the critical discount, δ_c^s, above which full risk sharing can be self-sustained if players follow trigger strategies and have standard selfish preferences. δ_c^s will be used for the comparison with the critical discount factor for reciprocity preferences, δ_c^r.

Proposition 4.2 *If households have standard selfish preferences, then in an infinitely repeated risk sharing game grim trigger strategies constitute subgame perfect equilibrium and the critical discount factor above which full risk sharing achieved can be given by:*

$$\delta_c^s = \frac{u(y^h) - u(\overline{y})}{\frac{1}{2}\left(u(y^h) - u(y^l)\right)}$$

Proof of Proposition 4.2 is given in the appendix. For reciprocity preferences, I consider two types of strategies, myopic and unforgiving trigger strategies. In myopic strategies, households play reciprocity Nash equilibrium of the stage game in every period of the infinitely repeated game. Proposition 4.3 below states that myopic strategies are an equilibrium of the repeated game.

Proposition 4.3 *If households have reciprocity preferences, then in an infinitely repeated risk sharing game G_∞, playing reciprocity Nash equilibrium, $\theta^* = 0$, and $\alpha_i^* = \alpha_j^* = 0$ of the stage game constitute SRE.*

Proof. Noting that the kindness function and feasible payoff are the same in every stage game, no player has any incentive to deviate from $\theta = 0$, and $\alpha = 0$ since it is a reciprocity Nash equilibrium of the stage game. ■

I now analyse the trigger strategies in G_∞. Proposition 4.4 below states that trigger strategies can be supported as SRE in G_∞.

Proposition 4.4 *If households have reciprocity preferences, then in an infinitely repeated risk sharing game G_∞, grim trigger strategies constitute a SRE and the critical discount factor, δ_c^r, above which the full risk sharing is self-enforcing is given by:*

$$\delta_c^r \geq \frac{u(y^h) - u(\overline{y}) + \frac{\eta}{2}\left(u(\overline{y}) - u(y^l)\right)}{\frac{1}{2}\left(u(y^h) - u(y^l)\right) - \frac{\eta}{4}\left(u(y^h) - u(\overline{y}) + 2u(y^l)\right)} \tag{12}$$

and $\eta \in [0, 2M]$.

Proof. Equilibrium beliefs: Households update their beliefs every period after nature draws the income pair. If the lucky household had continued participation in the previous period (when it was lucky last time), then in period t the unlucky household assigns probability 1 that the lucky household will make the transfer and the lucky household will assign probability 0 that the unlucky household will make a transfer. Only these beliefs are consistent with the strategy. If in any period t the lucky household defects, then in period $t+1$ both households play the reciprocity Nash equilibrium and that implies that in period $t+1$ and onwards beliefs will be $\alpha_i = \alpha_j = 0$.

Consider any period t, when both players have participated in the risk sharing in all previous periods. Suppose that ex-post household i reneges in period t (Household A reneges only if its income is higher), then household j's trigger strategy specifies that j plays reciprocity Nash equilibrium in all future periods. In period t, when i defects, j's belief is $\alpha_j = 1$ because i had continued to participate till $t-1$. Hence, i's utility in period t is:

$$\begin{aligned} & u(y^h) + \eta(\frac{1}{2} - 1)u(y^l) \\ = \ & u(y^h) - \frac{\eta}{2}u(y^l) \end{aligned}$$

and after period t household j will minmax household i and both players play reciprocity Nash equilibrium. Both players will update their beliefs and utilities and stop participating in risk sharing, $\alpha_i = \alpha_j = 0$ and $\theta_i = \theta_j = 0$. From period t onwards players receive their minmax utility $\underline{v}^r$ and their lifetime utility will be

$$\begin{aligned} \frac{\delta}{1-\delta}\underline{v}^r &= \frac{\delta}{1-\delta}\frac{1}{2}\left(\left(u(y^h) + \frac{\eta}{2}u(y^l)\right) + u(y^l)\right) \\ &= \frac{\delta}{1-\delta}\frac{1}{2}\left[\left(1+\frac{\eta}{2}\right)u(y^h) + u(y^l)\right] \end{aligned}$$

However, if i had not defected and continued to participation in full risk sharing, then its payoff in period t would have been

$$\begin{aligned} & u(\overline{y}) + \eta(\frac{1}{2} - 1)u(\overline{y}) \\ = \ & u(\overline{y})(1 - \frac{\eta}{2}) \end{aligned}$$

j would not have punished i and continue participation. In this case, i's lifetime expected utility $\frac{\delta}{1-\delta}v(\Theta)$ would be

$$\begin{aligned}\frac{\delta}{1-\delta}v(\Theta) &= \frac{\delta}{1-\delta}\frac{1}{2}\left(u(\overline{y}) + \eta(\frac{1}{2}-1)u(\overline{y}) + u(\overline{y}) + \eta(-0)u(\overline{y})\right) \\ &= \frac{\delta}{1-\delta}u(\overline{y})\left(1-\frac{\eta}{4}\right)\end{aligned}$$

Deviation for player i is unprofitable iff

$$u(y^h) - \frac{\eta}{2}u(y^l) + \frac{\delta}{1-\delta}\underline{v^r} \leq u(\overline{y})(1-\frac{\eta}{2}) + \frac{\delta}{1-\delta}v(\Theta)$$

substituting value of $\underline{v}$ and $v(\Theta)$ gives:

$$u(y^h) - \frac{\eta}{2}u(y^l) + \frac{\delta}{1-\delta}\frac{1}{2}\left[\left(1+\frac{\eta}{2}\right)u(y^h) + u(y^l)\right] \leq u(\overline{y})(1-\frac{\eta}{2}) + \frac{\delta}{1-\delta}u(\overline{y})\left(1-\frac{\eta}{4}\right) \tag{13}$$

rearranging 13 gives[16]:

$$\delta^r \geq \frac{u(y^h) - u(\overline{y}) + \frac{\eta}{2}\left(u(\overline{y}) - u(y^l)\right)}{\frac{1}{2}\left(u(y^h) - u(y^l)\right) - \frac{\eta}{4}\left(u(y^h) - u(\overline{y}) + 2u(y^l)\right)}$$

The condition $\eta \in [0, 2M]$ guarantees that the RHS is positive and less or equal to 1. ■

Proposition 4.4 implies that if households' sensitivity to intrinsic reciprocity is low, then full risk sharing can be self-enforcing with trigger strategies for any $\delta \geq \delta^r_c$. An immediate corollary of Proposition 4.4 is that the critical discount factor to support full risk sharing is greater when households have reciprocity preferences than when preferences are entirely selfish.

Corollary 4.1 $\delta^r_c \geq \delta^s_c$. *If household preferences represent intrinsic reciprocity, then the critical discount factor to support full risk sharing is greater than when households have selfish preferences.*

Proof. First note that in expression (12) setting $\eta = 0$ gives the critical discount factor for selfish preferences. It can easily be seen that with reciprocity term, $\eta > 0$, the numerator increases by $\frac{\eta}{2}\left(u(\overline{y}) - u(y^l)\right)$ and the denominator decreases by $\frac{\eta}{4}\left(u(y^h) - u(\overline{y}) + 2u(y^l)\right)$. Hence, the critical discount factor that can support full risk sharing increases. ■

[16] Steps of rearrangement are given in the appendix.

The intuition for Proposition 4.4 and Corollary 4.1 is that when players' preferences exhibit intrinsic reciprocity, instrumental reciprocity gets crowded out by intrinsic motivations. Risk averse household benefits from participating in the risk-sharing agreement in terms of their own material payoffs. However, cooperation from others based on entirely selfish motives makes participation less attractive, as players view others intrinsically unkind or selfish, i.e. high expectations (high α) from others are considered unkind. The two effects work in opposite directions, and this decreases the right hand side of the IC constraint (13) relative to standard selfish preferences. Moreover, the intrinsic reciprocity part of preferences makes defection less costly. When household i defects in period t, the term K_{ji} in its utility function remains the same whether it defects or not, as household j expects i to transfer the full risk sharing amount ($\alpha_j = 1$), but i's material payoff is higher if it defects. However, when j starts punishing i for defection and $\alpha_j \to 0$, i's overall utility is higher than standard preferences, when i's income is higher than j. When i's income is less than j's and $\alpha_j = 0$, the reciprocity part vanishes and i is left with just its own material payoff. Hence on average i's utility is higher in the punishment stage relative to the selfish preferences. These effects increase the lower bound on the critical discount factor, δ_c^r.

Let us now compare the level of informal insurance when players have reciprocal preferences with selfish preferences. Corollary 4.1 directly gives us the following reslut.

Proposition 4.5 *The level of informal insurance is greater if households have selfish preferences relative to reciprocity preferences:* $\frac{1}{\delta_c^r} \leq \frac{1}{\delta_c^s}$.

Proof. Immediate implication of Corollary 1 and the definition of level of risk sharing. ■

Proposition 4.5 states that the level of insurance will be lower under reciprocity preferences because a higher discount factor will be required to support the transfer.

5 Future Extension

As mentioned in the introduction, this is work in progress and in this section I describe how I plan to extend it in the future. First, the kindness function might depend on the past kindness of the other household. In this case, the kindness function K_{ji} would consist of two parts: past realized kindness, κ_{ji}, and current expectation based kindness ϑ_{ji}. Past kindness will be entirely backward looking and can be described as the discounted sum of past kindness (or unkindness) from

j towards i, summed up from period 1 to $\tau - 1$, where τ is the current time period. Since past kindness will be determined by past transfers of the other household, households can build a stock of kindness which could sustain defection for a limited period, till the stock of past kindness is exhausted. This can add another interesting strategic motive in the game and can explain why we observe partial instead of full insurance. Moreover, past kindness gives another channel for history to affect decisions in period t. This could provide another approach to model quasi-credit risk sharing in contrast to the "promised utilities" in the dynamic contract approach in Kocherlakota (1996) and Ligon et al. (2002).

6 Conclusion

Community-based risking sharing mechanisms are common features in developing countries. These informal risk sharing contracts are enforced without any formal legal enforcement. Limited commitment to informal contracts reduces the level of risk sharing achieved in these communities. Economists have traditionally relied on rational self-interest to explain these informal arrangements. However, explanations built on quid pro quo are not the only possible enforcement mechanisms. Emotions can also help enforce contracts, as stated by Fafchamps (2011). In this chapter, I have studied the classic risk sharing problem with the static limited commitment model under different preference structures, representing altruism, envy, and intrinsic reciprocity. My findings suggest that these emotions work in different directions; envy and altruism not only reduce the critical discount factor that can self-support risk sharing but also make the sharing mechanism more equitable. That implies that even at a lower patience level fairer distribution can be achieved. On the other hand, intrinsic reciprocity based on expectations and intentions can reduce the level of informal insurance by increasing the critical discount factor.

Chapter V

Appendix

1 A-1

Equilibrium Prices and Profits under Weight Pricing:

Mill 0's profits are given by (I drop the superscript w):

$$\pi_0 = \left(R - p_0(1 - \frac{s\overline{x}}{2})\right)\overline{x}$$

from (2) we know that $\overline{x} = \frac{t+p_0-p_1(1-s)}{2t+s(p_0+p_1)}$. The first order condition w.r.t. p_0 can be written as:

$$\begin{aligned} \frac{\partial \pi_0}{\partial p_0} &= R\frac{\partial \overline{x}}{\partial p_0} - p_0\frac{\partial \overline{x}}{\partial p_0} + \frac{sp_0\overline{x}}{2}\frac{\partial \overline{x}}{\partial p_0} - \overline{x}\left(1 - \frac{s\overline{x}}{2}\right) + \frac{sp_0\overline{x}}{2}\frac{\partial \overline{x}}{\partial p_0} = 0 \\ &= \frac{\partial \overline{x}}{\partial p_0}\left(R - p_0 + sp_0\overline{x}\right) - \overline{x}\left(1 - \frac{s\overline{x}}{2}\right) = 0 \\ \implies & \frac{\partial \overline{x}}{\partial p_0}\left(R - p_0 + sp_0\overline{x}\right) = \overline{x}\left(1 - \frac{s\overline{x}}{2}\right) \end{aligned}$$

Now using the expression for $\overline{x}$, we can evaluate $\frac{\partial \overline{x}}{\partial p_0}$

$$\frac{\partial \overline{x}}{\partial p_0} = \frac{(2-s)\left(t + sp_1\right)}{\left(2t + s\left(p_0 + p_1\right)\right)^2}$$

Since mills are symmetric, in equilibrium $p_0^* = p_1^* = p^*$ which implies that in equilibrium $\overline{x}^* = \frac{1}{2}$ and $\frac{\partial \overline{x}}{\partial p_0} = \frac{2-s}{4(ps+t)}$. Substituting these values into the first order condition above gives:

$$\frac{2-s}{4\left(p^*s + t\right)}\left(R - p^* + \frac{sp^*}{2}\right) = \frac{1}{2}\left(1 - \frac{s}{4}\right)$$

Solving for p^* gives the equilibrium prices under weight regime:

$$p^{w^*} = R(1 - \frac{s}{2}) - t(1 - \frac{s}{4})$$

Finally, substituting p^{w*} and $\overline{x}^*$ into the profit function π_0 gives:

$$\pi_0^w = \left(R - \left(R(1-\frac{s}{2}) - t(1-\frac{s}{4})\right)(1-\frac{s}{4})\right)\frac{1}{2}$$
$$= \frac{1}{2}t + \frac{s}{32}\left(\left(12-2s\right)R - \left(8-s\right)t\right)$$

<u>Calculations for Matrix 1: Equilibrium Prices</u>: Let $R = 2t = 1.3,\ t = 0.65,\ s = 0.10$

If both mills pay by weight, then the equilibrium prices are given by:

$$P^{w^*} = R(1-\frac{s}{2}) - t(1-\frac{s}{4})$$
$$= 2(0.65)\left(1-\frac{0.10}{2}\right) - 0.65\left(1-\frac{0.10}{4}\right) = 0.60125$$

If both mills pay by Sucrose content, then the equilibrium prices are given by:

$$P^{s*} = R - t$$
$$= 2(0.65) - 0.65 = 0.65$$

If one mill pays by Weight and the other pay by Sucrose Content:

Weight pricing mill (the real root): p_w

$p_w = -\frac{3}{4}\left(1.3\right)^2\left(0.10\right)^2 p_1 - \frac{5}{2}\left(1.3\right)^2\left(0.10\right)\left(0.65\right) + \frac{1}{2}\left(1.3\right)\left(0.10\right)^3 p_1^2$
$+\frac{9}{2}\left(1.3\right)\left(0.10\right)^2\left(0.65\right)p_1 - \frac{1}{2}\left(1.3\right)\left(0.10\right)^2 p_1^2 + 9\left(1.3\right)\left(0.10\right)\left(0.65\right)^2$
$-5\left(1.3\right)\left(0.10\right)\left(0.65\right)p_1 - 12\left(1.3\right)\left(0.65\right)^2 + \frac{1}{4}\left(0.10\right)^4 p_1^3 + \left(0.10\right)^3\left(0.65\right)p_1^2$
$-\frac{1}{2}\left(0.10\right)^3 p_1^3 - \frac{3}{4}\left(0.10\right)^2\left(0.65\right)^2 p_1 - \frac{5}{2}\left(0.10\right)^2\left(0.65\right)p_1^2 + \frac{5}{4}\left(0.10\right)^2 p_1^3$
$-\frac{9}{2}\left(0.10\right)\left(0.65\right)^3 + \left(0.10\right)\left(0.65\right)^2 p_1 + \frac{15}{2}\left(0.10\right)\left(0.65\right)p_1^2 + 12\left(0.65\right)^3$
$+12\left(0.65\right)^2 p_1 = 1.2025\times10^{-2}p_1^3 + 0.46605p_1^2 + 4.7119p_1 - 3.1994 = 0$
$p_w^* = 0.63407$
Sucrose pricing mill: p_s
$p_0 = \frac{1}{2}((1.3) - (0.65) + 0.63407 - (0.10)(0.63407)) = 0.61033$

<u>Calculations for Matrix 2: Equilibrium Prices</u>: $R = 2t = 1.3,\ t = 0.65,\ s = 0.05$

If both mills pay by weight, then the equilibrium prices are given by:

$$P^{w^*} = R(1-\frac{s}{2}) - t(1-\frac{s}{4})$$
$$= 2(0.65)\left(1-\frac{0.05}{2}\right) - 0.65\left(1-\frac{0.05}{4}\right) =: 0.62563$$

If both mills pay by Sucrose content, then the equilibrium prices are given by:

$$\begin{aligned} P^{s*} &= R - t \\ &= 2(0.65) - 0.65 = 0.65 \end{aligned}$$

If one mill pays by Weight and the other pay by Sucrose Content:

Weight pricing mill: p_w

$p_w = p_1 = -\frac{3}{4}(1.3)^2(0.05)^2 p_1 - \frac{5}{2}(1.3)^2(0.05)(0.65)$
$+\frac{1}{2}(1.3)(0.05)^3 p_1^2 + \frac{9}{2}(1.3)(0.05)^2(0.65) p_1$
$-\frac{1}{2}(1.3)(0.05)^2 p_1^2 + 9(1.3)(0.05)(0.65)^2$
$-5(1.3)(0.05)(0.65) p_1 - 12(1.3)(0.65)^2 + \frac{1}{4}(0.05)^4 p_1^3$
$+(0.05)^3(0.65) p_1^2 - \frac{1}{2}(0.05)^3 p_1^3 - \frac{3}{4}(0.05)^2(0.65)^2 p_1$
$-\frac{5}{2}(0.05)^2(0.65) p_1^2 + \frac{5}{4}(0.05)^2 p_1^3 - \frac{9}{2}(0.05)(0.65)^3$
$+(0.05)(0.65)^2 p_1 + \frac{15}{2}(0.05)(0.65) p_1^2 + 12(0.65)^3 + 12(0.65)^2 p_1$
$= 3.0641 \times 10^{-3} p_1^3 + 0.23823 p_1^2 + 4.8854 p_1 - 3.2474 = 0$
$p_w^* = 0.6443$
Sucrose pricing mill: p_s
$p_0 = \frac{1}{2}((1.3) - (0.65) + 0.63407 - (0.05)(0.63407)) = 0.62618$

<u>Calculations for Matrix 3: Equilibrium Profits</u>: $R = 2t = 1.3,\ t = 0.65,\ s = 0.10$
If both mills pay by weight

$$\pi_0^* = \frac{1}{2}t + \frac{s}{32}\left((12 - 2s)R - (8 - s)t\right)$$

$$\pi_0 = \frac{1}{2}(0.65) + \frac{0.10}{32}\left((12 - 2(0.10))(1.3)a - (8 - (0.10))(0.65)\right) = 0.35689$$

If both mills pay by Sucrose Content:

$$\Pi^{s*} = \frac{1}{2}t = \frac{0.65}{2} = 0.325$$

If one mill pays by Weight and the other by Sucrose Content:
$\pi_w^* = ((1.3) - (0.61033))\left(\frac{1}{2(0.65)+(0.10)(0.63407)}\begin{pmatrix} (0.65) + (0.61033) \\ +(0.63407)((0.10) - 1) \end{pmatrix}\right)$
$= 0.34886$

$\pi_w^* = -\frac{1}{2(2(0.65)+(0.10)(0.63407))^2}((0.65) - (0.61213) + (0.63407))$

$$\begin{pmatrix} (0.10)\,(0.610\,33)^2 + 4\,(0.65)\,(0.634\,07) \\ -4\,(1.3)\,(0.65) + (0.10)\,(0.610\,33)\,(0.634\,07) \\ -2\,(1.3)\,(0.10)\,(0.634\,07) - (0.10)\,(0.65)\,(0.634\,07) \end{pmatrix} = 0.324\,56$$

Equilibrium Profits in matrix 4, 5, and 6 are similarly calculated.

2 A-2

Proof of Lemma 3.1

Ex-post, household i's utility reduces to:

$$U_i(y^h, y^l, \beta) = u(y^h - \theta_i + \theta_j) - \beta \left(u(y^h - \theta_i + \theta_j) - u(y^l + \theta_i - \theta_j)\right)$$

Derivative with respect to θ_i is:

$$\frac{\partial \left(U_i(.)\right)}{\partial \theta_i} = -u'(y^h - \theta_i + \theta_j) - \beta[-u'(y^h - \theta_i + \theta_j) - u'(y^l + \theta_i - \theta_j)] \tag{1}$$

The derivative (1) is negavitve, $\frac{\partial U_i}{\partial \theta_i} < 0$, when $0 \leq \beta \leq \frac{u'(y^h)}{u'(y^l)+u'(y^h)}$. The household will choose the lowest possible transter. Hence the optimal transfer is $\theta_i^* = 0$. When $\frac{u'(y^h)}{u'(y^l)+u'(y^h)} < \beta \leq 0.5$, the optimal transfer is given by setting (1) equal to zero, and rearranging gives

$$\frac{u'(y^h - \theta_i + \theta_j)}{u'(y^l + \theta_i - \theta_j)} = \frac{\beta}{1-\beta} \tag{2}$$

The equilibrium behaviour of player i is characterized by equation (2). Finally, when $\beta > 0.5$, $\frac{\partial U_i}{\partial \theta_i} > 0$, we will have a corner solution $\theta_i^* = \frac{\Delta y}{2}$.

It remains to be checked that household j does not make any transfer. j's ex-post utility is

$$U_j(y^l, y^h, \alpha) = u(y^l - \theta_j + \theta_i) - \alpha \left(u(y^h + \theta_j - \theta_i) - u(y^l - \theta_j + \theta_i)\right)$$

Household j's FOC is:

$$\frac{\partial \left(U_j(.)\right)}{\partial \theta_j} = -u'(y^l - \theta_j + \theta_i) - \alpha[u'(y^h + \theta_j - \theta_i) + u'(y^l - \theta_j + \theta_i)] < 0$$

which implies $\theta_j^* = 0$

Proof of Proposition 3.2

Taking derivative of $\delta_c^{FS}(\beta, \alpha)$ with respect to β and α proves that the critical discount factor is decreasing altruism and envy parameters:

$$\frac{\partial\left(\delta_c^{FS}(\beta,\alpha)\right)}{\partial \alpha} = -\frac{2\left(u(y^h)-u(y^h-\theta)-\beta\left(\left(u(y^h)-u(y^l)\right)-\left(u(y^h-\theta)-u(y^l+\theta)\right)\right)\right)}{(\alpha-\beta+1)^2\left(\left(u(y^h)-u(y^l)\right)-\left(u(y^h-\theta)-u(y^l+\theta)\right)\right)} < 0$$

$$\frac{\partial\left(\delta_c^{FS}(\beta,\alpha)\right)}{\partial \beta} = -\frac{2\begin{bmatrix} \left(u(y^h) - u(y^l)\right) \\ -\left(u(y^h - \theta) - u(y^l + \theta)\right) - u(y^h) - u(y^h - \theta) \\ +\alpha\left(\left(u(y^h) - u(y^l)\right) - \left(u(y^h - \theta) - u(y^l + \theta)\right)\right) \end{bmatrix}}{(\alpha-\beta+1)^2\left(\left(u(y^h)-u(y^l)\right)-\left(u(y^h-\theta)-u(y^l+\theta)\right)\right)} < 0$$

For the second part, setting α and β equal to 0 gives:

$$\delta_c^S = \frac{u(y^h) - u(y^h - \theta)}{\frac{1}{2}\left(u(y^h) - u(y^l) - (u(y^h - \theta) - u(y^l + \theta))\right)} > \delta_c^{FS}$$

Which proves the Proposition.

Proof of Proposition 4.2

Consider any period t, and suppose that both players have participated in the risk sharing mechanism in all previous periods. Suppose now that ex post household A reneges in period t, then household B's trigger strategy specifies that B revert to autarky in all future periods. In period t Household A's utility is $u(y^h)$. After period t both household play autarky and their life time utility is $\frac{\delta}{1-\delta}\underline{v}$.

$$\frac{\delta}{1-\delta}\underline{v} = \frac{\delta}{1-\delta}\left(\frac{1}{2}\left(u(y^h) + u(y^l)\right)\right)$$

However, if A had not defected and continued to participate then its payoff in period t would have been $u(\overline{y})$ and B would have not punished A and continued the participation. In this case A's lifetime expected utility would be $\frac{\delta}{1-\delta}u(\overline{y})$. Deviation for player A is unprofitable iff

$$u(y^h) + \frac{\delta}{1-\delta}\underline{v} \leq u(\overline{y}) + \frac{\delta}{1-\delta}u(\overline{y})$$

$$u(y^h) + \frac{\delta}{1-\delta}\left(\frac{1}{2}\left(u(y^h) + u(y^l)\right)\right) \leq u(\overline{y}) + \frac{\delta}{1-\delta}u(\overline{y}) \tag{3}$$

rearrangning 3 gives:

$$\delta_c^s = \frac{u(y^h) - u(\overline{y})}{\frac{1}{2}\left(u(y^h) - u(y^l)\right)}$$

Derivation of δ_c^r

rewriting equation (13)

$$u(y^h) + \eta(\frac{1}{2} - \alpha_1)u(y^l) + \frac{\delta}{1-\delta}\frac{1}{2}\left[\left(1 + \frac{\eta}{2}\right)u(y^h) + u(y^l)\right] \leq u_A(\overline{y})(1 - \frac{\eta}{2}) + \frac{\delta}{1-\delta}u_A(\overline{y})$$

Rearranging gives:

$$\delta^r \geq \frac{u(y^h) - \frac{\eta}{2}u(y^l) - u(\overline{y})(1-\frac{\eta}{2})}{u(y^h) - \frac{\eta}{2}u(y^l) - u(\overline{y})(1-\frac{\eta}{2}) + u(\overline{y})(1-\frac{\eta}{4}) - \frac{1}{2}\left[\left(1+\frac{\eta}{2}\right)u(y^h) + u(y^l)\right]}$$

$$\delta^r \geq \frac{u(y^h) - \frac{\eta}{2}u(y^l) - u(\overline{y})(1-\frac{\eta}{2})}{u(y^h) - \frac{\eta}{2}u(y^l) + \frac{u(\overline{y})}{4}(2\eta - \eta) - \frac{1}{2}\left[\left(1+\frac{\eta}{2}\right)u(y^h) + u(y^l)\right]}$$

$$\delta^r \geq \frac{u(y^h) - \frac{\eta}{2}u(y^l) - u(\overline{y})(1-\frac{\eta}{2})}{u(y^h) - \frac{\eta}{2}u(y^l) + u(\overline{y})\frac{\eta}{4} - \frac{1}{2}\left[\left(1+\frac{\eta}{2}\right)u(y^h) + u(y^l)\right]}$$

$$\delta^r \geq \frac{u(y^h) - \frac{\eta}{2}u(y^l) - u(\overline{y})(1-\frac{\eta}{2})}{\left(1 - \frac{1}{2}\left(1+\frac{\eta}{2}\right)\right)u(y^h) - \left(\frac{\eta}{2} + \frac{1}{2}\right)u(y^l) + \frac{\eta}{4}u(\overline{y})}$$

$$\delta^r \geq \frac{u(y^h) - \frac{\eta}{2}u(y^l) - u_A(\overline{y})(1-\frac{\eta}{2})}{\frac{1}{2}\left(1-\frac{\eta}{2}\right)u(y^h) - \frac{1}{2}\left(\eta+1\right)u(y^l) + \frac{\eta}{4}u(\overline{y})}$$

$$\delta^r \geq \frac{u(y^h) - u(\overline{y}) + \frac{\eta}{2}\left(u(\overline{y}) - u(y^l)\right)}{\frac{1}{2}\left(u(y^h) - u(y^l)\right) + \frac{\eta}{4}\left(u(y^h) - u(\overline{y}) + 2u(y^l)\right)}$$

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[Chapter 2&3]

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[Chapter 4]

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