GUILT AND RECIPROCITY IN LABOR MARKETS AND THE DIFFUSION OF AGRICULTURAL INNOVATIONS

by

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As members of the Dissertation Committee, we certify that we have read the dissertation prepared by Benjamin Francis Zamzow entitled Guilt and Reciprocity in Labor Markets and the Diffusion of Agricultural Innovations and recommend that it be accepted as fulfilling the dissertation requirement for the Degree of Doctor of Philosophy.

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I hereby certify that I have read this dissertation prepared under my direction and recommend that it be accepted as fulfilling the dissertation requirement.

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In some sense the process of advanced academic study is one of learning to explore the frontiers of knowledge in order to return with new insights. This is at first accomplished under the guidance of experienced scholars with whose assistance one eventually learns to organize an expedition and to return with useful contributions without getting lost in the wilderness. As I now prepare to venture on future explorations, I thank my committee members for their guidance, instruction, and support: Martin Dufwenberg, Price V. Fishback, Derek Lemoine, and Mark Stegeman. I am particularly appreciative of their comments and insights as I developed and completed this dissertation.

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DEDICATION

For Buddy, whose achievements have already made me very proud.

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ABSTRACT

This dissertation consists of three essays:

The first essay considers a three-player labor market game and illustrates how wage and price decisions may change dramatically when a worker is guilt averse in the sense of wishing not to disappoint the firms consumers. I incorporate guilt aversion into an effort setting game and obtain predictions thereof in a way not yet considered by labor economists, and I call attention to the fact that one must exercise caution when directly applying Battigalli & Dufwenberg (2007) simple guilt preferences. The results demonstrate that a sufficiently guilt-averse worker will exert costly effort to produce a high quality good so as not to disappoint the consumer, thereby trading material value for psychological well-being.

The second essay seeks to understand the conditions under which the reciprocity motivation can alleviate sweatshop conditions. My co-author Martin Dufwenberg and I apply reciprocity preferences to a simple game designed to model a sweatshop. In this project we investigate the influence of a reciprocally behaving consumer on the firms treatment of the worker. We vary the level of information the consumer has about how the worker has been treated and observe how this affects predictions. We demonstrate that in order to predict appropriately alleviated sweatshop conditions the model must be adapted to allow for the consumer to be motivated by a salient regard for the firms treatment of the worker.

In the third essay I study the role played by experiment associations comprised of scientifically literate farmers in assisting agricultural experiment station researchers in the development of technology and in facilitating the diffusion of biological and non-biological innovation. I examine two such networks of unique structure, the Ontario Agricultural and Experimental Union and the Wisconsin Agricultural Experiment Association. I find that the seed distribution efforts of the Wisconsin

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Agricultural Experiment Association had an immediate statistically significant positive effect on the productivity of oats. I find that the program of experimentation of the Ontario Agricultural and Experimental Union had a delayed and statically significant positive effect on productivity of oats and peas.

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CHAPTER 1

PRICE AND QUALITY WITH A CONSCIENTIOUS WORKER

1.1 Introduction

When the quality of a good is assumed to be dependent upon a worker's effort selection, the temptation to shirk can have great consequences for market efficiency. If the negative effects of shirking on quality are severe enough, the market may break down and trade may cease. After all, consumers generally buy only when confident the good will be of sufficient quality. If this requires workers to exert high effort it is therefore in the firm's interest to keep the incidence of shirking to a minimum.

While this may be accomplished in a variety of ways I demonstrate that a firm may rely on the worker's guilt aversion to ensure high effort.[1] Rather than examine the case where a worker wishes not to disappoint his employer, I assume the worker wishes not to disappoint the consumer. I consider a market for a made-to-order good, a context in which this assumption is quite natural. Examples of this are things like concession stands, home repairs, and shoeshines. Here a worker experiences guilt when he believes that he is providing a lower quality product than the customer had expected.

In general these markets work as follows. A firm employs a worker who is asked to be available to create a good upon consumer request. The worker typically receives his wage regardless of the purchase decision made by the consumer. If the consumer requests a product, the worker must exert effort to create it. Crucially, the quality

[1] Other authors have offered models with predictions that avoid shirking. A well known example is the Shapiro-Stiglitz (1984) model in which firms pay an efficiency wage which leads to a no shirking equilibrium. This prediction arises in part because high wages create unemployment which makes the prospect of firing very unattractive to the worker. More recently Dufwenberg & Kirchsteiger (2000) show that reciprocally behaving workers will interpret high wages as kind and therefore respond with high effort.

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of the final product received by the consumer depends on the effort exertion of the worker. I am interested in the influence of guilt aversion on the effort choice of a worker and subsequently on the behavior of the consumer and firm. The following vignette will help place the context within which I am working and also introduces the relevant economic and psychological intuition:

Consider Bill, a worker who is paid a wage to operate a concession stand at municipally owned Beach Bay Amusement Park. No other firm or vendor is permitted to operate on the grounds and so the amusement park has the sole ability to sell to its attendees. His responsibilities include making and selling cotton candy and snow cones. When customers come to his window he takes their order and accepts payment before making the desired treat. Both snacks require preparation that is mildly unpleasant and Bill's chosen effort level determines the quality of the treat the customer actually receives. The cotton candy machine is loud and hot causing wisps of sugar to fly in his eyes and hair. He must take care to make sure the sugar mass adheres to the paper stick and has an appropriate level of fluffiness. The shaved ice from the snow cone machine freezes his fingers and he must keep it well stocked with fresh ice lest the product be watery. He must take care to make sure the flavoring is evenly dispersed and fills the bottom of the cone or else the treat may have a pleasant appearance but will taste bland. Of course there is a bare minimum effort level and associated quality level in order that the product actually constitutes cotton candy or snow cone and below which he would certainly be fired. However, Bill believes that choosing the minimum effort level means also that the resulting cotton candy or snow cone will disappoint his young customer. To the extent that Bill is sensitive to guilt he sets a high effort level so that he believes his creation meets the expectations of the consumer.[2]

[2]Imagine a young customer comes to Bill's window and orders a cotton candy. He may notice that the child is paying with crumpled bills and coins that had likely been squirreled away in a piggy bank for a special occasion. He believes this customer has high hopes for a very nice cotton candy. Under such circumstances it is reasonable for Bill to imagine that a small, matted cotton candy is quite disappointing. Further, Bill realizes that when he delivers the treat he will either see an expression of happiness or a downcast look.

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To capture this intuition I introduce a simple three player game and compare predictions under three policies. I show that when all players are selfish there is a unique sequential equilibrium that is inefficient. I demonstrate that if the firm incentivizes higher effort through the use of a monitoring and penalty system the efficient equilibrium arises. Finally, I show that this efficient equilibrium might be available at a lower cost to the firm when the worker is guilt averse. To this end, I work within the framework of psychological game theory and allow the worker to have belief dependent preferences. In the process I call attention to an issue pertaining to the direct application of the Battigalli & Dufwenberg (2007) model of simple guilt and I suggest an adaption for my game. Finally I compare the predictions under guilt aversion to those with the monitoring scheme.

1.2 Background

I model the basic interaction as a simple three player game that begins with a move by the firm, either In or Out. If the firm remains in the market by choosing In the consumer is called upon to move. On the other hand if the firm exits by choosing Out the game ends immediately. The consumer observes the choice of the firm and selects Buy or $Not\ Buy$. If the consumer (she) declines to make a purchase the game ends and otherwise the worker (he) receives the move. The worker observes the decisions of both previous players and then decides to exert high or low effort by choosing e_h or e_l respectively. The selection of e_h also implies a better product is created.

Payoffs are assigned according to the extensive game displayed in the left panel of Figure 1. If the game ends with the firm exiting the market, the firm and worker are assigned payoffs of zero while the consumer receives x. The parameter x corresponds to the value the consumer receives in the absence of the opportunity to buy from the firm. Although it stands to reason this should have no influence on the analysis I will vary this parameter to make important observations later on. If play proceeds to her decision node and the consumer chooses not to purchase the good, she receives

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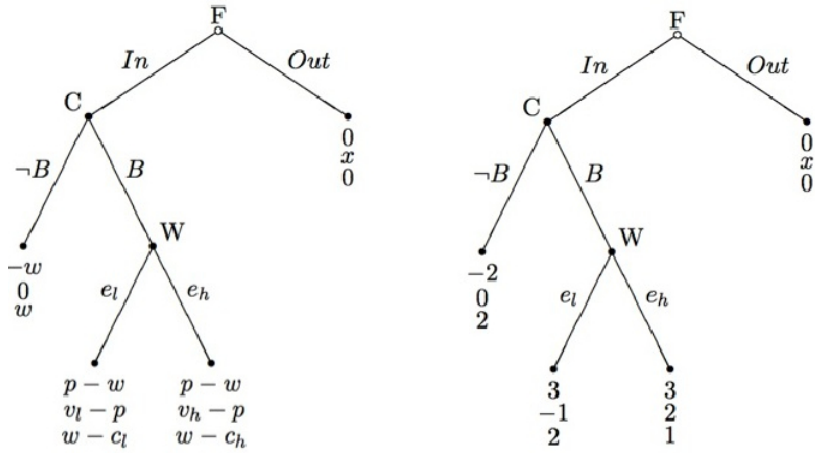
a payoff of zero. I assume the firm makes a wage payment, w, regardless of the consumer's purchase decision and therefore the payoffs to the firm and worker at this end node are $-w$ and w respectively. Finally at the two end nodes following the worker's effort choice, the payoff to the firm is equal to the price of the good minus the wage paid to the worker. The payoff to the consumer is the value of the good minus its price, $v_i - p$ where the worker's selection of e_i implies a value of v_i for $i \in \{l, h\}$. Finally, the payoff to the worker is his wage minus the cost of his effort level. I represent the costs associated with high and low effort selections with c_h and c_l respectively.

For the remainder of the paper I will focus on specific numerical examples in order to streamline the presentation. The first one I will consider is Γ_1 which arises when the parameters are assigned the following values: w=2, p=5, $v_h = 7$, $v_l = 4$, $c_l = 0$, $c_h = 1$. This game is displayed in the right panel of Figure 1.

Figure 1.1: Effort Setting Game



1.2.1 Classical Analysis

As a baseline reference it is useful to determine the prediction when all players are selfish and rational. The strategy profile $(Out, \neg Buy, e_l)$ is the backward induction solution and also the unique sequential equilibrium (SE) for all x. This equilibrium

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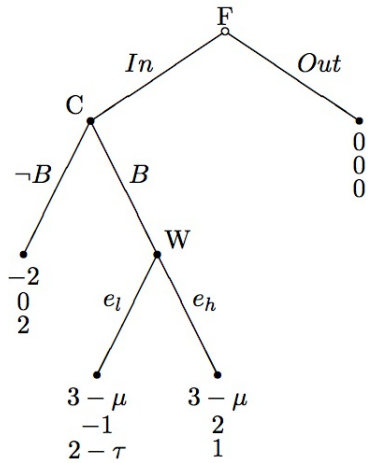
is inefficient since relative to the selfish prediction all players are better off with (In, Buy, e_h) when $x \leq 2$. The latter would occur as an equilibrium if players were to reasonably expect the worker to select e_h upon receiving the move and if he indeed selects high effort when called upon. Clearly this does not happen in the present model, but it may if additional structure is added.

1.2.2 Monitoring and Penalty Scheme

In this section I alter Γ_1 to allow the firm to exert some control over the worker. In Γ_1 if the firm were somehow able to ensure a high effort selection from the worker, the consumer would surely buy and the firm would receive a positive payoff. One way in which this is possible is if the firm were to monitor the worker and penalize low effort to the extent that the worker always exerts high effort. To bring this alive in the model, suppose the firm is able to monitor the worker at cost μ and penalize low effort by τ. The resulting game, Γ_2, is shown in Figure 2. Certainly in this new game as long as $\tau > 1$ the worker prefers to play e_h. Moreover, when the monitoring cost is such that $\mu < 3$, the strategy profile (In, Buy, e_h) is a sequential equilibrium for appropriate beliefs.

Figure 1.2: Effort Setting Game with Monitoring



While this structure makes the nice equilibrium available, there is reason to

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be concerned that monitoring may not be optimal for the firm to pursue in this context.[3] It may be possible for the firm to achieve the efficient outcome instead by relying on the conscience of the worker. If so, this could quite likely be accomplished at a lower cost to the firm than any sort of monitoring and penalty system. In fact, I will show that with a sufficiently guilt averse worker the firm no longer needs to monitor.

1.3 Guilt Aversion

To this point in the paper I have assumed that all players have selfish preferences. Henceforth, I will endow the worker with guilt aversion in the subgame that includes his decision node. This will have the following interpretation. When the worker believes the consumer receives a product of lower value than he believes was initially expected, the worker is affected by guilt. To the extent the worker anticipates feeling guilty for the consequence of his shirking, he may instead be motivated to select the higher effort choice.

In order to capture the correct intuition it is helpful to return to the vignette. One can imagine a little girl coming to Bill's window and ordering a cotton candy. He believes the little kid is expecting a stupendously fluffy, full cotton candy and will be sad upon receiving a small, matted one instead. While Bill finds high effort distasteful he also dislikes believing he has let down the consumer. Furthermore, Bill knows he will see the expression on the child's face as he delivers the cotton candy to her. In order to avoid feelings of guilt, Bill decides instead to invest higher

[3]There is a large literature on the effects of monitoring in principal-agent games. Frey (1993) observes that monitoring may have either a disciplining effect that increases effort or a crowding-out effect that decreases effort depending on the nature of the relationship between the firm and worker. Falk & Kosfeld (2006) find experimental evidence suggesting that agent effort selections decrease with increased monitoring in the sense of setting a minimum effort standard. Dickinson & Villeval (2008) present an experimental test of Frey (1993) in a principal-agent game and find that in the context of an interpersonal relationship monitoring has a negative effect on effort when the principal's payoff is increasing in the worker's effort.

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effort so that the end result matches his belief about what the child expects.

At this point it is important to pause and emphasize that I will be assuming that the worker has belief dependent utility. In addition to his material payoff, psychological considerations are also incorporated into the worker's utility. For this reason the use of psychological game theory is warranted in order to analyze this preference structure in a systematic framework. In this way I will be able to separate the worker's payoffs into material and belief-dependent, psychological components. The material component will just be the monetary payoffs shown in the game tree. In order to construct the psychological component of the payoff I will apply the model of simple guilt preferences from Battigalli & Dufwenberg (2007).

1.3.1 Incorporating Guilt Aversion

In this section I will introduce the mathematical structure useful to incorporate guilt aversion into the preferences of the worker. The formal treatment I begin with can be found in Battigalli & Dufwenberg (2007), henceforth BD (2007), which presents a general model of preferences incorporating guilt aversion and a solution concept that adapts sequential equilibrium (SE) to psychological extensive games.[4] The proper mathematical structure within which my paper fits is Battigalli & Dufwenberg (2009), henceforth BD (2009), which presents a general framework for psychological games and, quite importantly for my purposes, adapts extensive form rationalizability for application in psychological games.[5] To help familiarize the reader I will provide a brief description of BD (2007) simple guilt preferences, how-

[4]Guilt preferences were introduced into psychological game theory in Dufwenberg (2002), which applies psychological forward induction reasoning to get predictions in a simple two player extensive form game. This paper draws inspiration from Dufwenberg (2002) but instead considers a game with three players and, in addition, models guilt slightly differently.

[5]Recent work in the area of psychological game theory and guilt preferences has not been confined to theory. Several papers have investigated the predictions of guilt aversion in the laboratory. An early example is Dufwenberg & Gneezy (2000); more recently there have been papers testing the predictions of BD (2007) guilt aversion in the laboratory including Charness & Dufwenberg (2011) and Cardella (2012).

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ever, the following will provide the minimal explanation necessary and I refer the interested reader to the original for the full formalization.

In my paper the worker is affected by guilt aversion in his subgame and nowhere else. The other two players will retain selfish preferences throughout. For these reasons my treatment of BD (2007) simple guilt preferences is presented with respect to the worker only.[6] The worker lets down or disappoints the consumer if as a result of his strategy choice the consumer gets a lower monetary payoff than she had *initially* expected.

To operationalize this in my game, the consumer has a probability distribution over strategies and therefore has an initial conditional expected payoff, call $E_c^o[\hat{\pi}_c|h^o]$ where the initial history, or the root, is denoted by h^o. The worker does not have access to $E_c^o[\hat{\pi}_c|h^o]$ since this is a belief held by the consumer. Instead the worker forms his own initial expectation of the consumer's expected payoff which I will denote $E_{wc}^o[\hat{\pi}_c|h^o]$. The worker's initial expectation of the consumer's belief is therefore the amount of payoff the worker initially believes the consumer initially expects to receive. At his own decision node the amount by which the worker believes he disappoints the consumer is given by the difference $max\{0, E_{wc}^o[\hat{\pi}_c|h^o] - \pi_c\}$ where π_c is the actual payoff received by the consumer. That is to say that the consumer is disappointed when she receives a payoff lower than what she had initially expected to receive. The worker also has a sensitivity to guilt, θ_{wc}, governing the degree to which disappointment affects him. It is assumed that $\theta_{wc} \geq 0$ with equality meaning that guilt has no bearing on behavior. The utility function of the worker with simple guilt preferences is given by:

$$u_w = \pi_w - \theta_{wc} \cdot max\{0, E_{wc}^o[\hat{\pi}_c|h^o] - \pi_c\}$$

[6]BD (2007) actually present two versions of guilt aversion, simple guilt and guilt from blame. In my paper I will apply the definition of simple guilt which holds that the worker's guilt depends on how much he believes he disappoints the consumer. On the other hand, guilt from blame holds that the worker's guilt also depends on how much he believes the consumer believes he intended to let her down.

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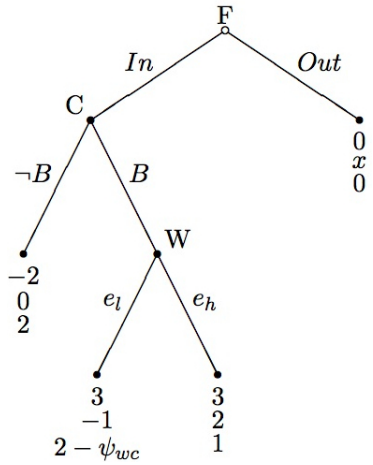
The game that arises from Γ_1 when the worker is guilt averse is displayed in Figure 3. I refer to this new game as $\Gamma_3(x)$ where x denotes the parameter in the consumer's payoff following the firm's decision to exit the market. In the game tree, the term ψ_{wc} represents the psychological component of the worker's payoff as discussed above. Observe that the worker's payoff at the end node following e_l is not a number but actually a function of beliefs. The payoff to the worker at this end node is crucially belief-dependent. For this reason the new game, $\Gamma_3(x)$, does not belong to the class of games considered by standard game theory. Instead, $\Gamma_3(x)$ is a psychological game of the variety introduced by Geanakoplos, Pearce, & Stacchetti (1989) and further studied by Battigalli & Dufwenberg (2009).

Figure 1.3: Effort Setting Game with Guilt



1.3.2 Insights from Battigalli & Dufwenberg (2009)

While the natural way to bring in guilt aversion is to follow BD (2007), in this game there will actually be a difficulty that arises from the direct application of these simple guilt preferences. In order to fully appreciate the issue I will motivate the problem by transporting the logic from an example found in BD (2009) into two variations of $\Gamma_3(x)$. This game has similar properties to $\Gamma_3(x)$ and will provide some insight as to what might happen in my game with the addition of simple guilt.

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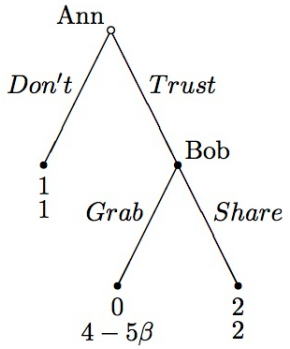
I will summarize their results and I direct the interested reader to the original for additional details. The BD (2009) trust game is displayed in Figure 4. There are two players in the game, Ann and Bob. Ann moves first and chooses either to continue the game by selecting $Trust$ or to end the game by choosing $Don't$. Payoffs following her choice of $Don't$ are $(1, 1)$. If she chooses to $Trust$ it becomes Bob's move and he may $Share$ or $Grab$. Payoffs following $Share$ are $(2, 2)$ and payoffs following $Grab$ are $(0, 4 - 5\beta)$. The term 5β appearing in Bob's payoff following $Grab$ reflects guilt he feels for having disappointed his co-player. Some additional details are necessary to make clear exactly how this works. Ann holds a beliefs α that Bob will share if she trusts, however, Bob does not have access to this belief. Instead Bob knows β which is his own expectation of Ann's belief, α. The 5 captures Bob's sensitivity to guilt.

Figure 1.4: Trust Game, BD (2009)



I begin the analysis by searching for a sequential equilibrium. At first it may seem uncontroversial that when β is quite large and when Bob dislikes disappointing Ann one should expect Bob to $Share$ whenever Ann $Trusts$. This actually turns out not necessarily to be the case. Certainly when Bob's guilt aversion is high and both players initially expect to follow the strategy profile $(Trust, Share)$, Bob will not deviate when he is called upon to play. He believes Ann initially expects a payoff of 2 and when he is highly guilt averse will not let her down. However, BD (2009) explain that in equilibrium players will never update their beliefs about the

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beliefs held by co-players. Therefore with SE reasoning if Bob receives the move unexpectedly he is incapable of holding beliefs that Ann expects him to *Share*. Bob is able to update his belief about the strategy that Ann is playing however he does not update about beliefs. For this reason if Bob initially expects that Ann will select *Don't* and he nevertheless finds himself at his decision node, he will select *Grab* regardless of his sensitivity to guilt. This being the case, for high sensitivities to guilt, there are multiple SE in the BD (2009) trust game. In light of this observation SE is actually somewhat unattractive when applied in psychological games and it may be more appropriate to employ a solution concept that allows for psychological forward induction reasoning.[7]

BD (2009) also determine the predictions of extensive form rationalizability which nicely captures the economic and psychological intuition that one may hope to model in this game. Contrary to the ambiguous prediction with sequential equilibrium they find a unique rationalizable outcome when Bob has a high sensitivity to guilt. Before explaining this result I will explain extensive form rationalizability as discussed in BD (2009). The key is the insistence on strong belief. If a proposition is strongly believed, players must always revise beliefs so as to maintain belief in that proposition as long as feasible. Relevant here is the insistence on strong belief in rationality. Strong belief in rationality has the consequence that whenever Bob is called upon to move he must believe Ann expects him to *Share* in order to retain his belief that she is rational. Whenever he receives the move, Bob believes Ann initially expects to receive a payoff of 2. Therefore when Bob's guilt aversion is high, he will in fact *Share*, and so extensive form rationalizability returns a unique prediction in the BD (2009) trust game.

To summarize the findings for high guilt sensitivity, when Bob has a strong sensitivity to guilt, the prediction of sequential equilibrium is ambiguous as either outcome is possible while the prediction of extensive form rationalizability is unique, Bob will always *Share*.

[7]Dufwenberg 2002 introduces psychological forward induction to model the effects of guilt in a simple marriage-investment game.

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1.3.3 Example of $\Gamma_3(0)$ with guilt averse worker

Having gained insights from the analysis of the BD (2009) trust game I will now turn to $\Gamma_3(x)$. I will consider two versions corresponding to when parameter x takes on values of 0 and -1. First I analyze $\Gamma_3(0)$. Intuitively the reader may recognize that the value of x should actually have no bearing on the behavior of the players in the game. It should be irrelevant to the consumer's expected payoff following the decision to purchase and therefore should not affect the degree to which the worker believes his actions potentially disappoint the consumer. However, it will turn out that when the worker is endowed with BD (2007) simple guilt preferences, which insists on referring to initial beliefs for assessments of guilt, the predictions are actually not invariant to changes in the value of x. I will discuss this in greater detail later.

In light of the findings with the BD (2009) trust game it is reasonable to expect multiple sequential equilibrium and a unique extensive form rationalizable outcome. But actually, the situation turns out to be much more complex. By calling attention to the predictions of both solution concepts for large guilt sensitivities, θ_{wc}, I will demonstrate that some care is warranted when applying the BD (2007) simple guilt preferences. An immediate observation is that when θ_{wc} is low, guilt aversion has no effect and a unique equilibrium is predicted, matching the classical prediction with both SE and extensive form rationalizability. For this reason my treatment will henceforth ignore the case of low θ_{wc}.

What happens when θ_{wc} is high enough to influence behavior? The strategy profile, $[In, Buy, e_h]$, can be supported as a SE for $\theta_{wc} \geq \frac{1}{3}$. To see this, note that no player will deviate. At their decision nodes the firm and consumer earn positive payoffs by remaining in the game and zero otherwise. More explanation is necessary for the worker. Observe that upon receiving the move the worker consults his own beliefs about the consumer's *initial* expected payoff which is 2. If the worker selects low effort the consumer will receive a payoff of -1, if he selects high effort her payoff will indeed be 2. The worker then selects high effort when $2 - \theta_{wc}(3) \geq 1$ which is

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true for $\theta_{wc} \geq \frac{1}{3}$.

On the other hand, can an equilibrium be sustained where the firm goes Out? It depends on sensitivity to guilt. The strategy profile $[Out, \neg Buy, e_l]$ means that the consumer expects payoff $x = 0$. In order for this to be an equilibrium it must be the case that the worker chooses e_l if called upon. What actually happens off the equilibrium path? When he unexpectedly receives the move the worker is able to update his beliefs about the consumer's strategy but not about her beliefs. This follows as a consequence of the logic of sequential equilibrium. BD (2009) explain that in equilibrium players will never update their beliefs about the beliefs held by co-players. Therefore, when assessing the degree to which he believes the consumer could be let down, the worker checks his initial beliefs about the consumer's initial expected payoff, which is $x = 0$. The low effort selection is made when $2 - \theta_{wc}(1) < 1$ or when $\theta_{wc} < 1$.[8] When $\theta_{wc} \geq 1$ there is a unique sequential equilibrium corresponding to the strategy profile, $[In, Buy, e_h]$.

These findings run contrary to what might be expected in two regards. First, the prediction of sequential equilibrium for high guilt sensitivities differs from the analogous prediction in the BD (2009) trust game in which multiple sequential equilibrium were predicted. Second, the fact that this result fails to obtain happens due to a feature of the three player structure of the game and in part due to an artifact of the consumer's payoffs. After all, when he is surprised with the move, the logic of sequential equilibrium prevents the worker from believing that the consumer expects him to exert high effort and therefore should protect him from being vulnerable to guilt. But, for large enough sensitivity to guilt he chooses e_h anyway. This is because as a consequence of BD (2007), the worker must live up to his *initial* belief about the consumer's *initial* expected payoff which here is $x = 0$. But this is not the correct psychology. Bill cares about what the child expects when she purchases the cotton candy, not her initial expectations, x, at some time prior to the amusement park's decision to open! In the next section I will discuss how predictions differ when the parameter x, and therefore initial beliefs, take on a different value. First,

[8] The prediction of SE is ambiguous when θ_{wc} takes on an intermediate value, $\theta_{wc} \in [\frac{1}{3}, 1)$.

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however, I will discuss the predictions of extensive form rationalizability.

Recall extensive form rationalizability imposes the requirement of strong belief in rationality. Here this means that even when receiving the move unexpectedly the worker must revise his beliefs so as to maintain his belief that the consumer is rational. The worker actually gets the rationality correct but this has no bearing on his own best response because he cares about the initial belief. Unlike in BD (2009) strong belief in rationality does not force the worker to change belief of payoffs. But simple guilt cares about the initial beliefs. Further it happens that the parameter x shapes predictions here.

The strategy profile $[In, Buy, e_h]$ is extensive form rationalizable for $\theta_{wc} \geq \frac{1}{3}$. To see this observe that a rational firm and rational consumer will both remain in the game. At his decision node the consumer is able to signal the expectation of at most 2 when selecting Buy. Upon receiving the move the worker consults his belief about the consumer's expectation. He believes a rational consumer expects a payoff of 2 and therefore he chooses between e_l and e_h according to: $2 - \theta_{wc}(3) \geq 1$ which is true for $\theta_{wc} \geq \frac{1}{3}$.

Can an equilibrium be sustained in which the firm goes Out? This requires that the worker selects e_l if called upon to move. For this to occur it must be the case either that the worker believes the consumer expects him to exert low effort, or the worker believes the consumer expects high effort exertion, but is insufficiently motivated by guilt aversion to care. Taken together the strategy profile $[Out, \neg Buy, e_l]$ is extensive form rationalizable for $\theta_{wc} < 1$. To see this, observe that when the worker receives the move unexpectedly in order to maintain his belief in the consumer's rationality, he believes that she expects a payoff of at least 0, the payoff received by the her choice of $\neg Buy$. However, while the worker correctly rationalizes the consumer's choice, for the purposes of assessing potential disappointment the worker looks to the consumer's initial expectation, $x = 0$. It is this belief that the worker must live up to. The worker gives the consumer a payoff equal to her initial expectation when e_h is chosen with probability one-third. The worker chooses e_l

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when $2 - \theta_{wc} > 1$ or when $\theta_{wc} < 1$.[9] For high guilt sensitivity, $\theta_{wc} \geq 1$, there is a unique prediction of $[In, Buy, e_h]$.

The argument provided in the foregoing discussion demonstrates that the model actually portrays the wrong psychology. While the worker correctly rationalizes the consumer's decision to Buy, again, it is the initial belief that is driving behavior. But, rather than care about the initial belief, it stands to reason the worker should care about the conditional belief which is signaled by the consumer's decision to Buy. Since it is the initial belief that matters here, if x took on other values the prediction would change! Therefore in some sense extensive form rationalizability delivers the correct prediction but based on the wrong reasons.

In summary, the results of the analysis of the game with both sequential equilibrium and extensive form rationalizability are partially contrary to what one may expect in light of the findings in the BD (2009) trust game. Unlike with the trust game, I instead showed that a unique prediction arises from SE for high θ_{wc}. On the other hand, similar to the trust game a unique prediction arises from extensive form rationalizability for high θ_{wc}. While a unique prediction was obtained with SE for high θ_{wc} things could have been different for other values of x. I will now demonstrate this with a concrete example by considering a slightly different game created by setting $x = -1$.

1.3.4 Example of $\Gamma_3(-1)$ with guilt averse worker

I now consider Γ_3(-1) which arises when $x = -1$. What happens for high values of θ_{wc}? The strategy profile, $[In, Buy, e_H]$ can be supported as SE for $\theta_{wc} \geq \frac{1}{3}$. To see this observe that when it becomes his move the worker must live up to his belief about the consumer's initial expected payoff of 2. The consumer receives a payoff of -1 when he chooses e_l and she receives a payoff of 2 when he chooses e_h. The worker exerts high effort when $2 - \theta_{wc}(3) \geq 1$ or when $\theta_{wc} \geq \frac{1}{3}$.

But, the strategy profile $[Out, \neg Buy, e_l]$ can be supported as a SE for $\theta_{wc} \geq \frac{1}{3}$ as well. When the worker unexpectedly finds himself with the move, he is able

[9] For values of $\theta_{wc} \in [\frac{1}{3}, 1)$ the predictions of extensive form rationalizability are ambiguous.

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to update his beliefs about the strategies the consumer played but not about her beliefs held at her decision node. Since BD (2007) simple guilt uses initial beliefs, the worker must live up to his belief about the initial expected payoff of -1. However the consumer gets -1 when the worker chooses e_l which means that guilt aversion presents no reason to exert high effort. Therefore the worker selects e_l if $2-\theta_{wc}(0) \geq 1$, which is always true! This shows that for values of θ_{wc} above one-third the prediction of sequential equilibrium is ambiguous.

What about the predictions of extensive form rationalizability? The strategy profile $[In, Buy, e_h]$ is extensive form rationalizable for $\theta_{wc} \geq \frac{1}{3}$. To see this observe that when players maintain belief in co-player rationality all players are best responding. For the firm $3 > 0$, for the consumer $2 > 0$, and for the worker $1 - \theta_{wc}(3) \geq 2$ assuming $\theta_{wc} \geq \frac{1}{3}$.

However, the strategy profile $[Out, \neg Buy, e_l]$ is also extensive form rationalizable for high values of θ_{wc}. This either requires that the worker believes the consumer expects a payoff of -1 or that the worker believes the consumer expects a payoff of 2, but is insufficiently motivated by guilt aversion for it to influence his behavior. The worker is always able to rationalize the belief that the consumer expects him to select e_l. To see this suppose that the worker finds himself with the move unexpectedly. Consulting his initial beliefs the worker believes the consumer has initially expected $x = -1$. Since the consumer gets -1 when the worker chooses e_l and 2 when he chooses e_h the worker can maintain his belief in the consumer's rationality and continue to belief that she expects him to select low effort. For these reasons despite potentially high values of θ_{wc} the worker is able to choose e_l without guilt aversion having an effect. Therefore this shows that extensive form rationalizability yields an ambiguous prediction for $\theta_{wc} \geq \frac{1}{3}$.

The preceding demonstrates that when the behavior of the worker is driven by initial rather than conditional beliefs, the predictions of the model depend on the value of the parameter x. When $x = 0$, the guilt averse worker will select e_h whenever called upon, however, when $x = -1$ the guilt averse worker is unable to be affected by guilt and is therefore may choose e_l. Either way the model captures

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incorrect intuition resting on initial beliefs which should plausibly be immaterial to the interaction in the subgame between the consumer and worker.

In summary both sequential equilibrium and extensive form rationalizability yielded ambiguous predictions for high values of θ_{wc}. Contrast this with the analysis of the trust game of BD (2009) wherein the SE prediction was ambiguous and rationalizability yielded a unique outcome. Moreover, these results differ from the predictions of $\Gamma_3(0)$ where a unique prediction arises for both solution concepts. The only difference was the value of x. So why are the predictions not invariant to changes in the parameter x? In the trust game Ann's initial beliefs and those she holds at the time of her move coincide. But in $\Gamma_3(x)$ due to the presence of the firm the initial beliefs of the consumer and those held at the time of her move are decoupled. Further, the payoffs to the consumer at the end node prior to her decision affect the worker's guilt assessment. The reason why this matters is the reliance on initial beliefs for simple guilt. The worker's belief about the consumer's initial expectation at the root determines extent of disappointment. But this seems a bit unreasonable. Not only should the prediction be invariant to changes in x but more precisely it stands to reason that in this game it might be more appropriate to allow the worker to assess his guilt relative to the beliefs the consumer holds at the time of his move. I make a natural adaptation to the model by allowing for this in $\Gamma_3(x)$. In the next section I will implement this adaption and discuss the predictions.

1.4 Adaptation to BD (2007) Simple Guilt

The model of simple guilt developed in BD (2007) can be modified as follows. Whereas previously the definition of simple guilt relied on the worker's beliefs about what the consumer initially expects now I make the relevant belief that which the consumer holds at the time of her move. At the time of her move the consumer has a probability distribution over strategies and therefore she has a conditional expected payoff given her strategy and beliefs. This is denoted by: $E_c[\hat{\pi}_c|h]$. The worker does

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not have access to this belief since it belongs to the consumer. Instead the worker forms his own expectation of this belief which I denote $E_{wc}[\hat{\pi}_c|h]$. I then write:

$$u'_w = \pi_w - \theta_{wc} \cdot max\{0, E_{wc}[\hat{\pi}_c|h] - \pi_c\}$$

As before the firm and consumer are assumed to retain selfish preferences and guilt aversion will become relevant in the subgame corresponding to the worker's effort decision.

1.4.1 Results with simple guilt adapted for $\Gamma_3(x)$

In this section I will apply the adapted version of simple guilt to the $\Gamma_3(x)$. Now that this adjustment has been made, it remains to go back and determine whether this makes a difference. A crucial observation is that the predictions of the model should be invariant to changes in the parameter x. With the adaptation to BD (2007) preferences the parameter x actually will be irrelevant. I therefore no longer consider $\Gamma_3(0)$ and $\Gamma_3(-1)$ separately.

So what are the predictions of SE in Γ_3 when the worker has the adapted version of simple guilt preferences? As in the BD (2009) trust game there are multiple equilibria for high guilt aversion. This result follows as a consequence of the no belief updating feature of SE and is shown below in Claim 1.

Claim 1 In Γ_3 for $x \in \{-1, 0\}$, and θ_{wc} is high, when the worker is endowed with BD (2007) simple guilt preferences adapted to depend on beliefs held at the time of the consumer's move:

- (i) When $\theta_{wc} \geq \frac{1}{3}$ both (a) (In, Buy, e_h) and (b) $(Out, \neg Buy, e_l)$ are possible SE.
- (ii) When $\theta_{wc} < \frac{1}{3}$ the SE is $(Out, \neg Buy, e_l)$.

Proof

- To verify (ia), it is enough to be sure there are no profitable deviations for any player. Receiving the move, the worker believes the consumer expects a

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payoff of 2 at the time of her move. Given consistent beliefs, the worker then calculates $2 - \theta_{wc}(3) \leq 1$ and so the worker indeed chooses e_h when $\theta_{wc} \geq \frac{1}{3}$. To verify (ib), suppose at the root play is expected to follow $[Out, \neg Buy, e_l]$. The worker believes that at the time of her move the consumer expected a payoff of 0 which is attainable when the consumer uses $\neg Buy$. However, the consumer has nevertheless instead chosen Buy. Finding himself with the move unexpectedly, the worker consults his beliefs about the consumer's expectations. The worker believes that the consumer still expects him to choose e_l; he is incapable of holding beliefs making him susceptible to guilt. The worker chooses e_l regardless of θ_{wc}.

- To verify (ii), show that there are no profitable deviations for any player. When guilt aversion is weak, the classical solution obtains. The worker never selects e_h so the consumer never Buys and the firm never goes In.

The above demonstrates that as with the trust game in BD (2009), the analysis of Γ_3 using sequential equilibrium yields ambiguous predictions for high values of θ_{wc}. The psychology of guilt aversion matches the vignette, but the logic of sequential equilibrium leads to predictions that do not match the intuition. With SE when Bill finds himself with the move unexpectedly he is not able to hold the belief that the worker expects high effort and therefore even with high guilt sensitivity, Bill is able to exert low effort. Recall that with ordinary simple guilt preferences this did not happen, but another issue arose. The prediction there was of a unique sequential equilibrium in which the worker chose high effort in order to live up to an initial belief.

So what happens when extensive form rationalizability is applied to Γ_3? With the adaptation to BD (2007) simple guilt preferences a forward induction argument goes through. The consumer is able to signal an expected payoff the belief about which the guilt averse worker must live up to. The prediction is for a unique equilibrium corresponding to the strategy profile $[In, Buy, e_h]$ when the worker is highly guilt averse.

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Claim 2 In $\Gamma_3(x)$ for $x \in \{-1, 0\}$ when the worker is endowed with BD (2007) simple guilt preferences adapted to depend on beliefs held at the time of the consumer's move and θ_{wc} is high:

- (iii) There is a unique psychological extensive form rationalizable equilibrium, $[In, Buy, e_h]$
- (iv) For low values of θ_{wc} the prediction is $[Out, \neg Buy, e_l]$.

Proof Suppose play is expected to follow (In, Buy, e_h). When the consumer chooses Buy she signals the belief in a payoff of 2. The worker believes that the consumer believes he will choose e_h with probability 1. Given the adapted version of simple guilt preferences, the worker pays attention to the consumer's expectation held at the time of her move when assessing guilt, an anticipated payoff of 2. The consumer receives a payoff that is below this expected value when low effort is chosen and one that exceeds this expected value when high effort is selected. Therefore the worker selects high effort when $2 - \theta_{wc}(3) \leq 1$, or when $\theta_{wc} \geq \frac{1}{3}$. Given common strong belief in rationality the consumer (and firm) must also figure this out.

Suppose initially each player believes play will follow $(Out, \neg Buy, e_l)$, but the worker is unexpectedly called upon to play. Observe when the firm selects a price offer it signals to the consumer an expectation of a payoff of at least 0 which could have been obtained by going out. Maintaining strong belief in the firm's rationality the consumer believes the firm expects her to Buy. Having received the move the consumer updates her expected payoff to at least 0 achievable by ending the game with $\neg Buy$. Should the consumer choose to Buy the most she can signal to the worker that she expects is a payoff of at least 0. When it becomes the worker's move he believes that the consumer believes he will choose e_h with probability of at least $\frac{1}{3}$. With this adaptation to the modeling of his simple guilt preferences, the worker pays attention to the consumer's expectation held at the time of her move when assessing guilt, an anticipated payoff of 0. Seeing that the consumer receives a payoff that is below this expected value when low effort is chosen and one that exceeds this expected value when high effort is selected the worker selects

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high effort when $2 - \theta_{wc}(0) \leq 1$, or when $\theta_{wc} \geq 1$. Given common strong belief in rationality the consumer must also figure this out. Therefore, $[Out, \neg Buy, e_l]$ is not rationalizable in $\Gamma_3(x)$ for high values of θ_{wc} with this adaptation to BD (2007) simple guilt preferences.[10]

This result demonstrates that when extensive form rationalizability is applied to the game in which the worker is endowed with BD (2007) simple guilt preferences adapted to be sensitive to beliefs held at the time of the consumer's move, both the modeling of guilt aversion and the prediction accord with the intuition from the vignette. After all, Bill assesses his degree of guilt relative to the expectation held by the consumer at the time of her purchase and his predicted behavior is driven by this conditional belief. When Bill is sufficiently guilt averse he will exert high effort so as to avoid disappointing the consumer.

Taken together these predictions of SE and extensive form rationalizability align with the predictions in the BD (2009) trust game. The findings in Claim 1 show that there are multiple SE and the findings in Claim 2 show that there is a unique rationalizable outcome. Importantly, Claim 2 has displayed the intuition that one might hope to capture. In particular the guilt averse worker lives up to his expectation of the consumer's belief at the time of her move. When the worker is sufficiently guilt averse he will exert high effort whether he initially expected the consumer would make a purchase or not.

1.5 Concluding remarks

What I have now shown is two-fold. First, I have demonstrated that in order to incorporate guilt aversion into this game it is best not to apply BD (2007) directly. The predictions of the two versions of the model are drastically different and this is somewhat surprising. After all, the BD (2007) simple guilt preferences were designed with sequential games in mind and have performed well thus far.[11] In fact, it may

[10] For intermediate values of $\theta_{wc} \in [\frac{1}{3}, 1)$, the prediction is ambiguous.

[11] Examples of this are the experimental studies of Cardella 2011 and Charness & Dufwenberg 2011.

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well have been the case that initial beliefs held by the consumer and worker at the beginning of the game were sufficient here as well. This turns out not to be the case. The issue, of course, is not that the game is sequential but rather that here initial beliefs do not coincide with those held at the consumer's decision node. BD (2007) simple guilt preferences require the guilty party to consider his own initial beliefs about the initial beliefs of the player he wishes not to disappoint. In all applications of BD (2007) to date this player's decision node has occurred at the root and so initial beliefs have coincided with those held at the time of the move. This is not the case in my game since play begins with a move by the firm while the worker feels guilt aversion with respect to the consumer who moves second. I have now shown in this context when wishing not to let down the consumer the worker must actually reflect upon beliefs held at the time of the consumer's move.

I have also demonstrated that guilt aversion is enough to change predictions in the game and that the resulting model matches the psychological and economic intuition from the vignette. Here the worker's assessment of the degree to which he may let down the consumer is measured relative to the beliefs held by the consumer at the time of her move. This corresponds to Bill assessing his potential disappointment of the young customer relative the the beliefs he holds about her expected payoff at the time she purchases the cotton candy. If Bill is sufficiently sensitive to guilt, the firm is able to count on his high effort selection even in the absence of monitoring. Presumably the firm may simply need to incur some fixed cost to induce guilt, for instance, making arrangements so that the worker and consumer interact when the good is transferred. As long as Bill is guilt averse and knows he will need to see the expression on the customer's face, he will avoid shirking. When this is true, the consumer will buy and the firm stays in the market.

Earlier I had mentioned that the firm could pursue a scheme of monitoring as an alternative to avoid the inefficient equilibrium. However, at the end of the day the firm may actually prefer to play Γ_3 to Γ_2. That is, the firm may prefer to induce guilt in the worker over the option of monitoring in order to ensure high effort. This will certainly be the case whenever both are available and when $\mu > 0$, since the

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firm will have a strictly higher payoff when it allows the worker's guilt aversion to bring about the efficient outcome.

Finally, it should be noted that I have not proposed a general modification of BD (2007). It is not immediately clear that a general treatment improving upon BD (2007) is possible. It is uncertain what such a model might look like. In the present context it was appropriate to focus on beliefs held at the time of a player's move for assessing guilt. However, in many other cases initial beliefs work just fine. In some contexts it might even be optimal to use terminal beliefs. I do suspect that at the end of the day the best advice is for applied economists to make changes as needed for their particular contexts, but further research may nevertheless be warranted in this regard.

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CHAPTER 2

SWEATSHOPS AND RECIPROCITY

2.1 Introduction

Many of the goods that consumers purchase in western countries are manufactured elsewhere, and often the same good will be produced in several factories and even in multiple countries. This happens as profit maximizing firms award their production contracts to the low-cost suppliers and sometimes this results in production taking place under very poor working conditions and even in sweatshops. Further, profit maximizing firms have little incentive to prevent contracts from going to sweatshops until someone blows the whistle and raises government or consumer attention. When external pressure is high enough a profit maximizing firm will respond and sometimes be proactive. For example Nike has developed well publicized monitoring programs to keep an eye on the conditions under which their own products are made.[1] This anecdotal evidence is suggestive of the firm's perception that consumers care about labor conditions. Further empirical evidence suggests that concern for labor conditions held by consumers is strong enough for the effect to have economic significance in the marketplace. Hiscox and Smyth (2006) conducted a field experiment at ABC Carpet and Home in Manhattan and demonstrate that placing labels attesting to ethical labor conditions on goods allowed stores to charge up to 20% more while at the same time seeing an increase in sales. Rode, Hogarth, and Le Menestrel (2008) find that consumers in the laboratory will pay a price premium for ethically differentiated products thereby reducing their experimental gains. On the other hand these participants were less willing to pay a premium for products differentiated only by costs. Perhaps understanding these motivations provides a partial explanation for Gap's 2007 announcement that it would be using 'child labor free' labels on some

[1] http://www.businessweek.com/magazine/content/04 38/b3900011 mz001.htm

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of its goods.[2]

Nevertheless it is not clear that concerned consumers can easily avoid buying products made in sweatshops. While consumers generally realize that sweatshops exist, it is difficult to become aware of actual labor conditions in the absence of disclosure by the firm or monitoring organizations, and firms who fail to closely monitor their suppliers (and even those who do) run the risk of doing business with sweatshops. Further it is not easy for concerned consumers to avoid sweatshops by simply refusing to buy from companies known to have had products produced at sweatshops in the past. Even in the present time many major apparel companies are linked to factories with sweatshop labor conditions.[3][4] One could try to avoid products made by those companies but often this severely restricts one's buying options. For instance a consumer could stop buying from Nike, but many of the close substitutes including products sold by Adidas, Asics, and Puma have all dealt with their own links to sweatshops.[5]

From this discussion it can be noted that there are certain circumstances that may need to occur in order for consumer behavior to change and therefore to influence behavior of the firm. It may be the case that consumers must both know that sweatshops exist and on some level feel that it is desirable to improve those labor conditions. Also it seems consumers need to have information about specific companies and products associated with sweatshop labor. This paper considers whether a reciprocity motivation and one or both of these factors are required for the labor conditions of the worker to be improved through the influence of consumers. The first consideration is accounted for through consumer's preferences and the second through a parameter that captures the treatment of the worker and which the consumer may or may not be able to observe. To accomplish its goals the paper constructs three games from a basic game form in order to investigate the extent

[2]http://www.guardian.co.uk/business/2007/nov/04/3

[3]http://www.guardian.co.uk/global-development/poverty-matters/2011/apr/28/sweatshops-supplying-high-street-brands

[4]http://www.sfgate.com/cgi-bin/article.cgi?file=/c/a/2002/09/27/MN180746.DTL

[5]http://www.oxfam.org.au/explore/workers-rights/are-your-clothes-made-in-sweatshops

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to which these factors are needed. The first is a default case in which all players have standard selfish preferences and the consumer is unconcerned about sweatshop labor, the second allows that the consumer has preferences for reciprocity with the firm based on Dufwenberg & Kirchsteiger (2004), and the third introduces consumer preferences for indirect reciprocity with the firm on behalf of the worker. In each of the three games the analysis is performed both with and without the consumer having the ability to observe the treatment of the worker.

While this paper is most immediately interested in examining these issues in the presence of reciprocity it is certainly also possible to conceive of models involving different behavioral assumptions about consumer motivations such as inequality aversion and altruism, or to allow regard for the worker to enter the payoff of the consumer directly. Many of these may even lead to similar conclusions. It is also possible to build competition into the analysis and doing so does seem to favor the worker particularly when firms elect to compete in the parameter governing worker treatment. Nevertheless for the purposes of the present paper the analysis will focus on games that involve reciprocity without competition. The modeling in this paper will abstract away some details such as the process of contracting with supply factories and other market participants and will instead assume that the firm employs the worker directly and has a single consumer. Elimination of the contracting process and of additional firms, consumers, or workers is justified on the grounds that it is desirable to develop a simple stylized model that does not exactly reproduce reality but nevertheless is rich enough to allow for insights into the issues of interest.

2.2 The Model

This exercise begins from the starting point of a basic game form involving three players assigned roles of firm, consumer, and worker. The firm makes an offer to the consumer, (ϕ, p) with $\phi, p \in [0, 1]$, where these parameters are defined as a share of profits between itself and the worker, and the price to be paid by the consumer, re-

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spectively. The parameter ϕ which is literally a share of the profits will be assumed to capture labor conditions experienced by the worker. The consumer will choose a strategy with structure dependent on whether ϕ is observable. When ϕ is not observable the consumer's strategy, $q : [0, 1] \to [0, 1]$, is defined by $q(p)$, and when ϕ is observable the strategy, $q : [0, 1]^2 \to [0, 1]$, is defined by $q(\phi, p)$. When no particular context is implied, the consumer's strategy will simply be referred to as $q(\cdot)$. The worker has a singleton strategy set and trivially opts for the outcome determined by the consumer and firm. From this game form three games will be constructed and considered each in turn under the cases of observable and unobservable ϕ. First all players have classic preferences, next the consumer is endowed with preferences for reciprocity as described in Dufwenberg & Kirchsteiger (2004), and finally the consumer has preferences for indirect reciprocity based on a variation to DK (2004). In the subsequent analysis both conditions of observability will be considered and compared. Given the payoffs below, ϕ will be present in the structure of each game whether the consumer is aware of its value or not.

The classic game adds the following (material) payoffs to the existing form:

- $\pi_F[p, \phi, q(\cdot)] = \phi p q(\cdot)$
- $\pi_W[(p, \phi, q(\cdot)] = (1 - \phi) p q(\cdot)$
- $\pi_C[p, \phi, q(\cdot)] = (1 - p) q(\cdot)$

The payoffs to the firm and worker are intuitive: with the assumption of zero costs these are simply shares of the profit with proportion to each player determined by $\phi \in [0, 1]$. The payoff to the consumer has box demand structure since the consumer's marginal utility and surplus per unit is $(1 - p)$. This means that the marginal effect of p is constant, -1, so for a given price there is a constant valuation of each unit; with this type of demand at any constant price $p \in [0, 1]$ the consumer will buy any quantity $q \in [0, 1]$ lending the 'box' structure.

The classic analysis of the game begins by noting that since ϕ does not enter the consumer's maximization problem it makes no difference whether ϕ is observable

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or not since a selfish and rational consumer ignores it either way. With ϕ holding no sway over the behavior of the consumer a profit maximizing firm will always choose $\phi = 1$. This has the result of the firm giving no share of profit to the worker i.e. full exploitation. Furthermore, the firm will always choose $p = 1$ because the consumer always uses the strategy of $q(\phi, p) = 1$, for all offers. In equilibrium the firm captures all surplus. To see this observe that the logic is similar to that used in studying ultimatum bargaining. Any offer involving either $p < 1$ or $\phi < 1$ cannot be part of an equilibrium since there will always be some $p' > p$ or $\phi' > \phi$ for which the consumer will still use the strategy $q(\phi, p) = 1$ and which yields strictly higher payoff to the firm. Moreover there can be no equilibrium in which the firm chooses $p = 1$ & $\phi = 1$ and consumer chooses $q(\phi, p) \neq 1$ since the firm can then obtain a strictly higher payoff by lowering the price a tiny bit to where the consumer does choose $q(\phi, p) = 1$. Indeed, the subgame perfect equilibrium is unique.

2.2.1 Dufwenberg & Kirchsteiger (2004)

This section introduces the DK (2004) model and discusses its application in the present context. Using this model two new games are constructed using the basic game form and classic preferences as a starting point and then endowing the consumer with preferences for reciprocity with the firm. A game using the DK (2004) model is considered because it is possible that giving the consumer preferences for reciprocity is sufficient to alleviate working conditions. The logic here is that it may be the case that the firm is able to derive a benefit from improving the treatment of the worker just as a consequence of its strategic interaction with the consumer. This will be considered in greater detail in Section 2.2. Also, the DK (2004) framework is extended to model indirect reciprocity and used to build another game. There the consumer's reciprocal behavior toward the firm is on behalf of the worker in response for how the worker is being treated. This will be considered in greater detail in Section 3.

In DK (2004) the authors present an intentions based reciprocity model in the context of finite multistage games that will be adapted to the present paper. There

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are some relevant differences between the DK (2004) presentation of the preference structure and the present game. Contrary to the original environment this paper involves infinite strategy sets, does not consider mixing, and sometimes lacks multi-stages as in the cases of unobservable ϕ to be discussed later. Nevertheless the spirit of the model may still be applied. Since only the consumer will have preferences for reciprocity while the firm and worker retain classical selfish preferences the DK (2004) model will be introduced and discussed relative to the consumer. When given this preference structure the consumer's payoff becomes separated into material and reciprocity payoffs:

$$U_C(\cdot) = \underbrace{(1-p)q(\cdot)}_{\text{material payoff}} + \underbrace{Y_{CF} \cdot \kappa_{CF}(\cdot) \cdot \lambda_{CF}(\cdot)}_{\text{reciprocity payoff}};\ Y_{CF} > 0$$

Material payoff is simply the consumer's classic payoff function. This is what the consumer obtains in the absence of psychological considerations. The reciprocity payoff is the product of three terms. The first, Y_{CF}, is a parameter that captures the degree to which the consumer cares for reciprocity with the firm and will be understood as strictly positive. The second, $\kappa_{CF}(\cdot)$, is defined as the consumer's kindness to the firm. This is a first-order belief; the consumer's belief about his treatment of the firm. The third, $\lambda_{CFC}(\cdot)$, is defined as the consumer's perception about the firm's kindness toward him. This is a second-order belief; the consumer's belief about the firm's belief about how kind it is being to the consumer. It is through this term that the consumer assesses the firm's intention and through $\kappa_{CF}(\cdot)$ that the consumer responds.

In DK (2004) players wish to match the signs of $\kappa_{ij}(\cdot)$ & $\lambda_{iji}(\cdot)$ in order to maximize the reciprocity payoff. Essentially the consumer wishes to treat the firm the way the consumer believes the firm has treated him. However, here the consumer can only be unkind or neutral; that is, the consumer can only make $\kappa_{CF}(\cdot) \leq 0$. This is because DK (2004) requires that players use efficient strategies, those for which there exist no other strategies that are at least as good for every player and better for someone. Observing the classic payoff functions for the three players

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one may immediately recognize that the only efficient strategy for the consumer is $q(\cdot) = 1$ for all arguments. Therefore the consumer has no scope for positive reciprocity. On the other hand, the firm has no inefficient strategies. This issue is relevant when calculating kindness and perceived kindness functions. Both are done relative to a player's equitable payoff which is defined as the average of the maximum and minimum payoffs that can be efficiently given to a player in principle. Then $\kappa_{CF}(\cdot)$ is defined as the material payoff the consumer believes he gives the firm minus the firm's equitable payoff. Similarly, $\kappa_{FC}(\cdot)$ is defined as the material payoff the firm believes he gives the consumer minus the consumer's equitable payoff and is important only insomuch as it is necessary for the calculation of $\lambda_{CFC}(\cdot)$ which is defined as the consumer's belief about $\kappa_{FC}(\cdot)$. In order to fully describe the kindness function a bit more must be said regarding beliefs. The firm holds a first-order belief about the consumer's strategy, this is $q'(\cdot)$. The consumer holds a second-order belief about the firm's belief about this strategy, this is $q''(\cdot)$. With these beliefs it is possible to mathematically define $\kappa_{CF}(\cdot)$ and $\lambda_{CFC}(\cdot)$, and here this will be done from the standpoint of the case in which ϕ is observable.

Following the offer (ϕ, p) the kindness of the consumer toward the firm may be calculated. When the consumer uses strategy $q(\cdot)$ the payoff to the firm is equal to $\phi p q(\cdot)$. The most the consumer can efficiently give the firm is ϕp and the least the consumer can efficiently give the firm is ϕp. The average of these, the equitable payoff to the firm, is ϕp. So, the kindness of the consumer to the firm when playing strategy $q(\cdot)$ may be calculated according to $\kappa_{CF}(\cdot) = \phi p q(\cdot) - \phi p$ which reduces to $\phi p[q(\cdot) - 1]$. This can take on value of zero when the consumer chooses $q(\cdot) = 1$ and a value of $-\phi p$ when the consumer chooses $q(\cdot) = 0$. It can never be positive. Since the firm will only ever be endowed with standard preferences there is no need to calculate perceived kindness from the point of view of the firm.

The kindness of the firm to the consumer, $\kappa_{FC}(\cdot)$, must be calculated in order to obtain the consumer's belief about the firm's kindness. This depends on the payoff to the consumer, $(1 - p)q(\cdot)$, and the maximum and minimum payoffs the firm can see to it the consumer obtains. Unlike the consumer all strategies of the

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firm are efficient so the firm can efficiently give the consumer a payoff of zero. The maximum payoff the firm can give the consumer is $(1-\underline{p})q'(\cdot)$ where $\underline{p}$ is the price that maximizes consumer payoff. Similarly where $\overline{p}$ is the price that minimizes the consumer's material payoff the minimum payoff the firm can give the consumer is $(1-\overline{p})q'(\cdot)$. So the firm's kindness to the consumer is given by $\kappa_{FC}(\phi, p, q''(\cdot)) = \{(1-p)q'(\cdot) - \frac{1}{2}[(1-\underline{p})q'(\cdot) + (1-\overline{p})q'(\cdot)]\}$.

The consumer's belief about the firm's kindness, the consumer's perceived kindness, has the same mathematical structure but with second order beliefs regarding the consumer's belief about the firm's belief about the consumer's strategy: $q''(\phi, p)$. This is what makes $\lambda_{CFC}(\cdot)$ into the consumer's belief about how kind the firm intends to be toward the consumer. The consumer's perceived kindness regarding its treatment by the firm is given by the function $\lambda_{CFC}(p, q''(\cdot)) = \{(1-p)q''(\cdot) - \frac{1}{2}[(1-\underline{p})q''(\cdot) + (1-\overline{p})q''(\cdot)]\}$. Perceived kindness may be positive, negative, or zero depending on the values of $q''(\cdot)$ and p, $\underline{p}$, and $\overline{p}$.

DK (2004) introduces the solution concept of sequential reciprocity equilibrium (SRE) which imposes the requirement that each player is maximizing utility at all information sets given players' strategies and correct beliefs which are updated as subgames are reached. Since DK preferences are not attributed to the firm or worker in this particular context it will be required that the consumer maximizes utility with correct beliefs all over. It is now possible to begin considering the implications for types of equilibria that are possible. There will certainly be multiple equilibria and it will be desirable to make some reasonable assumptions that will limit the types of equilibria allowed. However, three observations about what certainly cannot happen in equilibrium will first be demonstrated through examples. First these observations are stated:

- The 'classic' subgame perfect equilibrium is not SRE.
- The opposite case from the 'classic' solution in which the consumer uses $q(\cdot) = 0$ for all arguments is not SRE.
- The consumer's selection of a constant $q(\phi, p) \in (0, 1)$ does not occur in SRE.

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First observation: The classic SPE is not a SRE. If it were, the firm selects $(\phi, p) = (1,1)$ expecting the consumer to play $q(\phi, p) = 1,\ \forall(\phi, p)$. In other words, the firm holds the belief that $q'(\phi, p) = 1$ and consumer holds the belief that $q''(\phi, p) = 1$, so $\lambda_{CFC} = (1-p)(1) - \frac{1+0}{2} = \frac{1}{2} - p$. If the consumer stays on this strategy $\kappa_{CF} = 0$ and if the consumer deviates, $\kappa_{CF} = -1$. Either way the consumer's material payoff is zero. The consumer deviates if $Y_{CF}(-1)(-\frac{1}{2}) \geq Y_{CF}(0)(-\frac{1}{2})$. This reduces to the inequality $\frac{1}{2} \geq 0$ which always holds, so the consumer always deviates and this is not SRE.

Second observation: The consumer's use of $q(\cdot) = 0$, for all arguments, is not a SRE. Suppose it is an equilibrium. Then the consumer plans to buy nothing for any offer so the firm holds the believe $q'(\cdot) = 0$ and consumer holds the belief $q''(\cdot) = 0$. With these beliefs the consumer cannot possibly perceive the firm as unkind and this being the case the consumer has no reason to be unkind to the firm. Both $\lambda_{CFC}(\cdot)$ and $\kappa_{CF}(\cdot)$ are zero and reciprocity plays no role. More formally: Following an arbitrary offer of (ϕ, p), the consumer deviates when $(1-p)(1) + Y_{CF}(0)(0) \geq (1-p)(0) + Y_{CF}(0)(0)$, which always holds.

Third observation: The consumer's use of any constant $q(\phi, p) \in (0, 1)$ is not a SRE. To see this observe that if it were the case that the consumer uses $q(\cdot) \in (0, 1)$, the firm could offer an arbitrarily lower price, say, $p - \epsilon$ for a small enough $\epsilon > 0$ such that $q(\cdot) = 1$. However since there is no such uniquely small ϵ in the real numbers the best response of the firm does not exist. So this is unsustainable as a SRE.

With these observations it is possible to see that several outcomes are unsupportable as SRE. Nevertheless, multiple equilibria still remain. In fact, there are some that may strike the reader as initially surprising. For example, consider the case where the consumer selects the strategy $q(\cdot) = 0$ for all arguments except for some (ϕ, p) where $p > 0$. This is actually sustainable as a SRE because of self-fulfilling prophecies. The logic required here is that the consumer adopts a particular strategy that forces the beliefs of both parties to be of the following sort: The consumer believes the firm thinks he is not unkind when a particular offer is made so when that particular offer occurs the consumer is in fact not unkind in responding; on

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the other hand if any other offer is made the consumer believes the firm thinks he is unkind so when such an offer is actually made the consumer is in fact unkind in response.

Fourth Observation: The consumer's use of the strategy $q(\cdot) = 0$*, for all arguments except for some* (ϕ^*, p^*) *s.t.* $p > 0$ *is sustainable as a SRE.* When the firm offers (ϕ^*, p^*) the consumer holds the belief $q''(\cdot) = 1$. Given the consumer's adherence to this strategy the firm maximizes the material payoff to the consumer by choosing $p = p^*$ and minimizes it by choosing some $p \neq p^*$. So $\lambda_{CFC}(\cdot) = \{(1-p)q''(\cdot) - \frac{1}{2}[(1-\underline{p})q''(\cdot) + (1-\overline{p})q''(\cdot)]\}$ which becomes: $\lambda_{CFC}(\cdot) = \{(1-p)q''(\cdot) - \frac{1}{2}[(1-p^*)]\}$. The consumer stays the course when: $(1-p^*)(1) \geq 0 + Y_{CF}(-\phi^* p^*)[(1-p^* q''(\cdot)) - \frac{1}{2}(1-p^*)]$. This is always true given that: $(1-p^*) \geq -Y_{CF}(\phi^* p^*)[\frac{1}{2}(1-p^*)]$, in fact with strict inequality. If the firm were instead to choose some $\hat{p} \neq p^*$ then the consumer holds the belief $q''(\hat{\phi}, \hat{p}) = 0$ and so the consumer stays the course and is unkind when: $(1-\hat{p})(0) + Y_{CF}(-\hat{\phi}\hat{p})[(1-\hat{p})q''(\cdot) - \frac{1}{2}(1-p^*)] \geq (1-\hat{p})(1)$ or $Y_{CF}(-\hat{\phi}\hat{p})[(1-\hat{p})(0) - \frac{1}{2}(1-p^*)] \geq (1-\hat{p})$ or $Y_{CF}(\hat{\phi}\hat{p})[\frac{1}{2}(1-p^*)] \geq (1-\hat{p})$ which holds for adequate Y_{CF}.

As shown in the preceding example there are multiple equilibria that can arise in sometimes counterintuitive ways. It is desirable to impose some reasonable assumptions that will provide a sort of structure to the $q(\cdot)$ that will emerge in equilibrium. The first assumption, (i), is motivated by the self-fulfilling prophecy example and ensures that lower prices are viewed as no less kind independently of everything else including beliefs about ϕ. This disallows the consumer from holding beliefs that cause lower prices to appear less kind relative to expectations of higher ones. A second assumption, (ii), requires that the consumer will buy as often as it does not hurt him to do so. This more or less ensures that the behavior of the consumer sticks as close to classical behavior as possible. These two assumptions are as follows:

- (i): $\forall\, p, p' : p < p'$; *implies* $\lambda_{CFC}(p, \cdot) \geq \lambda_{CFC}(p', \cdot)$
- (ii): If $q(\cdot)$ is part of SRE, then there does not exist $\hat{q}(\cdot) \neq q(\cdot)$ also part of SRE such that $\hat{q}(\cdot) \geq q(\cdot)$, $\forall$ arguments.

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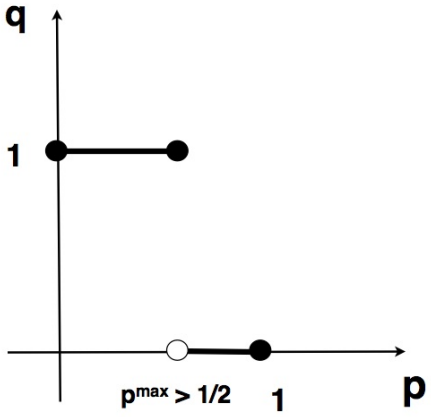
Assumptions (i) and (ii) together with the observation in Example 4 imply that $q(\cdot)$ in equilibrium will have the structure of a step function as depicted in Figure 1 where $q(p) = 0$ until some $p^{max} > \frac{1}{2}$ after which point $q(p) = 1$. While this has been shown in the context of unobserved ϕ as it turns out $q(\phi, p)$ looks very similar at least under DK (2004) preferences.

Figure 2.1: Structure of $q(p)$ in Equilibrium



2.3 Results With DK Reciprocity

Now that the DK (2004) model has been introduced this section will show how it is actually applied and details the results that will be obtained. While this preference structure does not directly consider the treatment of the worker, it will be argued that it is at least conceivable that this is enough to help out the worker nonetheless. Given the specification of the model it is possible the firm could trade off ϕ for price increases and more than compensate while reducing the consumer's benefit to using negative reciprocity. This possibility will be investigated in the next two subsections.

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2.3.1 No Transparency of Sweatshop Conditions: ϕ Unobserved

In this subsection the game considered is that where the consumer is endowed with DK (2004) preferences and is unable to observe the actual sweatshop conditions of the firm's worker. This is the benchmark case for the context of DK (2004) reciprocity. Here the consumer forms beliefs about the firm based on how the firm treats him. The consumer knows that sweatshops exist but has no reason to suspect that the firm operates one and cannot verify either way.

Since ϕ is unobservable this means that $\phi = 1$ since the firm has no reason to lower it given that the consumer could not possibly recognize this or respond favorably. With ϕ unobserved by the consumer the firm's choice of $\phi \neq 1$ is tantamount to a voluntary pay-cut and such behavior is out of character for a profit maximizer. To find p^{max} suppose that the firm has offered some price p and some share ϕ, in this case $\phi = 1$. Of course ϕ is unobserved by the consumer but nonetheless part of the problem as it enters the payoff to the firm. For this reason the consumer's strategy is represented by $q(p)$ and $\phi = 1$ enters the kindness functions only insomuch as it is relevant to the firm's payoff. To obtain $\kappa_{CF}(p, q(p))$ note that the maximum and minimum that the consumer can efficiently give the firm are both now p. The average of these values, or the equitable payoff due the firm, is just p so the function capturing the kindness of the consumer to the firm is represented by $\kappa_{CF}(p, q(p)) = p[q(p) - 1]$. Therefore $q(p) = 1$ implies that the consumer's kindness to the firm is zero, or that he is not being unkind, while $q(p) = 0$ implies that the consumer's kindness to the firm is $-p$. As discussed earlier, the consumer has only the capacity to be unkind, so only negative reciprocity is relevant in the analysis.

To obtain $\lambda_{CFC}(\cdot)$, notice that the maximum the firm can give the consumer is 1, which occurs by offering $p = 0$. The minimum that the firm can efficiently give the consumer is zero which is guaranteed by the offer of $p = 1$. The average of these two is $\frac{1}{2}(1) + \frac{1}{2}(0) = \frac{1}{2}$. So the perceived kindness of the consumer about the firm is $\lambda_{CFC}(p, q(p)) = (1 - p) - \frac{1}{2} = \frac{1}{2} - p$.

With these two kindness functions it is now possible to consider the consumer's

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decision between responding with $q(p) = 0$ or $q(p) = 1$. The latter is chosen if:

$$1 - p + Y_{CF} \cdot 0 \cdot (\frac{1}{2} - p) \geq 0 + Y_{CF}(-p)(\frac{1}{2} - p)$$
$$(1 - p) \geq Y_{CF}(p^2 - \frac{p}{2})$$
$$\frac{(1-p)}{(p^2 - \frac{p}{2})} \geq Y_{CF}$$

To maximize profit the firm wants to choose the price that makes this condition hold with equality. It is possible to get an idea of what the profit maximizing price will look like. Rearranging the above inequality yields the quadratic, $0 = Y_{CF}p^2 + \frac{2-Y_{CF}}{2}p - 1$, which may be solved for p^{max-dk} by applying the quadratic formula and selecting the positive root to give: $p^{max-dk} = \frac{\frac{Y_{CF}}{2} - 1 + \sqrt{1 + 3Y_{CF} + \frac{Y_{CF}^2}{4}}}{2Y}$ when $Y_{CF}p^2 + (1 - \frac{Y_{CF}}{2})p - 1 = 0$.

Proposition 1 Assuming (i) and (ii), and consumer endowed with DK preferences, and ϕ unobserved: in any equilibrium the firm will offer $(1, p^{max-dk})$ and the consumer will use the strategy $q(p) = 1$ for any $p \leq p^{max-dk}$ and $q(p) = 0$ for any $p > p^{max-dk}$.

Proof: The firm cares to maximize profit and does this by obtaining the highest possible ϕ and p. It knows that ϕ is invisible to the consumer and therefore the firm has the incentive to keep it as high as possible, $\phi = 1$. Examining the consumer's decision between $q(p) = 1$ and $q(p) = 0$ leads to the following inequality: $(1 - p) \geq Y_{CF}(p^2 - \frac{p}{2})$. To complete the proof observe the condition for the inequality to hold: $Y_{CF} \leq \frac{1-p}{p(1-\frac{1}{2})}$, and note that the firm chooses the price at which this holds with equality, p^{max-dk}.

This shows that when the consumer had DK (2004) preferences and ϕ is unobserved there is no incentive for the firm to improve treatment of the worker. However the consumer is clearly getting a better price than under classic preferences. At any rate the best chance for these preferences to alleviate sweatshop conditions would be in the event that ϕ is observable, and that case is considered in the following subsection.

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2.3.2 Transparency of Sweatshop Conditions: ϕ Observed

In this subsection the game considered involves the consumer having DK (2004) preferences for reciprocity as well as awareness of the actual sweatshop conditions. This awareness may be due to investigative journalism, reports from watch groups, or even self-disclosure on behalf of the firm. It is at least conceivable now that the firm takes advantage of this awareness and offers $\phi < 1$ so as to undermine the degree to which it is possible for the consumer to be motivated to retaliate against low price offers. Observe because ϕ enters into the kindness function of the consumer, κ_{CF}, when $\phi < 1$ the reciprocity product is diminished. When the consumer is unkind, this function takes on the value ϕp which is clearly decreasing in magnitude with lower ϕ. Could it be the case that the firm actually offers $\phi < 1$ while making up for it with an increased price all the while with the consumer is less inclined to choose $q(\cdot) = 0$, perhaps to the extent that the firm can exploit this tendency? Actually as is shown in Proposition 2 this is not the case. It makes no difference if ϕ is observed or not since the firm prefers $\phi = 1$ in both cases; the firm never lowers ϕ and does not try to affect the consumer's ability to use negative reciprocity.

Proposition 2 When the consumer is endowed with DK preferences and is able to observe ϕ, the firm sets $\phi = 1$ in any equilibrium.

Proof: The relevant inequality is: $(1-p)+Y_{CF}\cdot 0\cdot(\frac{1}{2}-p) \geq 0+Y_{CF}(-\phi p)(\frac{1}{2}-p) = Y_{CF}(\phi p)(p-\frac{1}{2})$. This leads to the condition, $\phi p \leq \frac{1-p}{Y_{CF}(p-\frac{1}{2})}$. Note that the LHS is just the firm's payoff. Profit is increased with higher ϕ and higher p. Now consider the effect of lowering $\phi < 1$ and increasing p on the size of the RHS. It is clear that ϕ does not appear on the RHS, but the numerator is decreasing in p while the denominator is increasing in p. Both of these effects make for a smaller fraction. That is, overall the RHS is decreasing in p. So, the firm cannot gain by using $\phi < 1$.

Since the firm will not benefit by using some $\phi < 1$ even though ϕ is observed the equilibrium will look just like the results where it was unobservable. This is stated at Proposition 3. This corresponds to the situation where the consumer is made aware of the specific sweatshop conditions but is only concerned with how it

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is treated by the firm and ignores the worker.

Proposition 3 Assuming (i) and (ii), and consumer endowed with DK preferences, with ϕ observed: in any equilibrium the firm will offer $(1, p^{max-dk})$ and the consumer will use the strategy $q(p) = 1$ for any $p \leq p^{max-dk}$ and $q(p) = 0$ for any $p > p^{max-dk}$.

Proof: The firm cares to maximize profit and does this by obtaining the highest possible ϕ and p. It knows that the consumer can now see ϕ and nevertheless for the reasons above it has the incentive to keep it as high as possible which is still $\phi = 1$. Examining the consumer's decision between $q(\phi, p) = 1$ and $q(\phi, p) = 0$ results in the following inequality: $(1 - p) \geq Y_{CF}(p^2 - \frac{p}{2})$. To complete the proof observe the condition for the inequality to hold: $Y \geq \frac{1-p}{p(1-\frac{1}{2})}$, and note that the firm chooses the price that forces equality, p^{max-dk}, identical to the result found when ϕ was unobserved.

At this point one can pause and reflect on what has been done. Here the consumer has been assumed to care for reciprocity between itself and the firm. In particular the consumer's belief about the firm's kindness has depended on its own treatment by the firm. It was shown that regardless of the consumer's ability to observe ϕ the worker has not been helped. However, it can be noted that the consumer is still clearly better off here than in the subgame perfect equilibrium resulting from the classic analysis. Recall that under standard preference assumptions the firm captures all of the surplus. Here the consumer is aware of the sweatshop conditions but is not sufficiently motivated to behave differently. Instead the consumer purchases the good simply at the lowest possible price which, as in the previous section where sweatshop conditions are unobservable, gives the consumer a share of the surplus.

2.4 Results With Indirect Reciprocity

In this section the consumer will be endowed with preferences for indirect reciprocity based on a variation to the DK (2004) model. This corresponds to the possibility

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that anti-sweatshop campaigns have had the effect of shifting consumer attention away from concern about one's own treatment by the firm instead toward that of the worker. It is possible even that additional advertisements or publicity actually increases the consumer's sensitivity parameter which is now written as Y_{CW}. Relevant for reciprocity considerations is now the consumer's belief about the kindness of the firm to the worker whereas earlier where it was consumer's belief about the kindness of the firm to the consumer. Essentially the consumer wishes to treat the firm the way the consumer believes the firm has treated the worker. Mathematically, the effect on consumer behavior that needs to be modeled here is now λ_{CFW}, rather than λ_{CFC} which had appeared in the model previously. Since material payoffs have not changed nor has the definition of the function representing the kindness of the consumer to the worker there is again no scope for positive reciprocity.

Once again certain assumptions are desirable. These are similar to the ones made before to suit the DK (2004) preference structure, but need to be updated to fit the present game. Whereas under DK preferences it did not matter whether ϕ was observed or not since the firm always set $\phi = 1$, here the firm will conceivably use $\phi < 1$. So, there are now three types of equilibria that become sustainable by self-fulfilling prophecy analogous to Example 4:

- (1) Consumer uses $q(\cdot) = 0$ for all (ϕ, p), but $q(\cdot) = 1$ for some (ϕ^*, p^*), where $\phi^*, p^* > 0$
- (2) Consumer uses $q(\cdot) = 0$ for all (ϕ, p), but $q(\cdot) = 1$ for some $(\cdot, p^*)$, where $\phi^*, p^* > 0$
- (3) Consumer uses $q(\cdot) = 0$ for all (ϕ, p), but $q(\cdot) = 1$ for some $(\phi^*, \cdot)$, where $\phi^*, p^* > 0$

Fifth Observation: Equilibria of the form described above, (1), (2), and (3) may be supported by self-fulfilling prophecies as SRE.

Proof: The consumer's perception about the kindness of the firm toward the worker is given by: $\lambda_{CFW}(\cdot) = \{(1-\phi)pq''(\cdot) - \frac{1}{2}[(1-\phi)pq''(\cdot)]\}$ where the second part

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of the difference is the maximum payoff the firm can given the worker in principle while the consumer uses $q(\cdot)$. For cases (1)-(3) the consumer uses $q(\cdot) = 1$ when the exact offer is made and $q(\cdot) = 0$ otherwise, and therefore $q''(\cdot) = 1$ and $q''(\cdot) = 0$ for these circumstances, respectively. In case (1) this amounts to the offer (ϕ^*, p^*) which if made means that the consumer holds the belief $q''(\cdot) = 1$ and will indeed use $q(\cdot) = 1$ when $(1 - p^*) \geq -Y_{CW}(\phi^* p^*)[\frac{1}{2}(1 - \phi^*)p^*]$ which always holds. On the other hand if the firm offers some $(\phi, p) \neq (\phi^*, p^*)$ then the consumer holds the belief $q''(\cdot) = 0$ and will indeed use $q(\cdot) = 0$ when $(1 - p) \leq Y_{CW}(-\phi p)[-\frac{1}{2}(1 - \phi)p]$ which is $(1 - p) \leq Y_{CW}(\phi p)[\frac{1}{2}(1 - \phi)p]$ and holds for adequate Y_{CW}. Similar logic demonstrates (2) and (3).

The following assumptions are desirable to impose a reasonable structure on $q(\cdot)$ that will emerge in any equilibrium.

- (i'_a) $\forall$ ϕ, ϕ' and for some p, $\phi \leq \phi'$ *implies* $\lambda_{CFW}(\phi, p, \cdot) \geq \lambda_{CFW}(\phi', p, \cdot)$
- (i'_b) $\forall$ p, p' and for some ϕ, $p \leq p'$ *implies* $\lambda_{CFW}(\phi, p, \cdot) \geq \lambda_{CFW}(\phi, p', \cdot)$
- (i'_c) $\forall$ ϕ, ϕ', p, p': $\phi \leq \phi'$ & $\phi p \leq \phi' p'$ *implies* $\lambda_{CFW}(\phi, p, \cdot) \geq \lambda_{CFW}(\phi', p', \cdot)$
- (ii') if $q(\cdot)$ is part of some SRE, then there does not exist $\hat{q}(\cdot) \neq q(\cdot)$ also part of SRE such that $\hat{q}(\cdot) \geq q(\cdot)$, for all arguments.

The first assumption (i'_a) is analogous to (i). It insists that lowering ϕ is viewed as more kind for a given p. The second assumption, (i'_b), is similar and insists that lower prices are viewed as more kind as long as ϕ is held constant. Assumption (i'_c) allows that the lower ϕ is viewed as more kind even when paired with a price that is higher, but not too high. The last assumption (ii') simply requires the consumer to purchase the good whenever it does not hurt to do so. If there is a lower ϕ that gives the consumer something he can accept, although this may not always be the case, then he needs to do it. With these assumptions the structure of $q(\cdot)$ in equilibrium is similar to how it looked under DK (2004), but in two dimensions since what happens with ϕ is now more complex.

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2.4.1 No Transparency of Sweatshop Conditions: ϕ Unobserved

In this subsection the game considered involves a consumer endowed with preferences for indirect reciprocity. The consumer will now wish to respond with negative reciprocity if the firm is sufficiently unkind to the worker. It is possible now that through advertisement campaigns the degree to which the consumer wishes to respond to the firm on behalf of the worker is increased. Nevertheless here the consumer is unable to actually observe or verify labor conditions.

Suppose the firm makes an offer consisting of a price, p, that is observed and a share, ϕ, that is unobserved. As before, the firm will still set $\phi = 1$ since the consumer is ignorant of the true value of ϕ and therefore it is impossible for the consumer to respond favorably to the firm for decreases in its value. In order to examine the consumer's response decision the reciprocity payoff must be obtained. The kindness function describing the consumer's treatment of the firm is once again given by $\kappa_{CF}(p, q(p)) = p[q(p) - 1]$. The perceived kindness function governing the consumer's belief about how the firm is treating the worker is slightly different from its form under DK preferences. When ϕ is not observed this is now given by $\lambda_{CFW}(\phi, p, q(p)) = (1 - \phi)pq(p) - \frac{pq(p)}{2}$, or $-\frac{p^{max}}{2}$ since $\phi = 1$ in SRE where p^{max} is understood to be the most the firm could give the worker in principle. It is now possible to consider the consumer's decision regarding $q(\cdot)$. The consumer uses $q(\cdot) = 1$ when $1 - p + Y_{CW}(0)(0 - \frac{p^{max}}{2}) \geq 0 + Y_{CW}(-p)(0 - \frac{p^{max}}{2})$ which reduces to the condition $(1 - p) \geq Y_{CW}\frac{p \cdot p^{max}}{2}$. This condition is then solved setting $p^{max} = p$, and yielding:

$$1 - p \geq Y_{CW}\frac{p^2}{2}$$

$$\frac{2(1-p)}{p^2} \geq Y_{CW}$$

When price offers satisfy this inequality the consumer uses $q(\cdot) = 1$, and in order to maximize profit the firm wants the price where this holds with equality. It is possible to determine what the profit maximizing price will look like. To solve for the maximum price paid by the consumer, p^{max-ir} which is at equality, and beginning with $1 - p + Y_{CW}(\frac{\phi p}{2})(\frac{p}{2} - \phi p) \geq 0$, and letting $\phi = 1$ this yields: $1 - p - \frac{Y_{CW}}{2}p^2 = 0$.

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Solving by the quadratic formula and selecting for the positive root:

$$p^{max-ir} = \frac{\sqrt{1+2Y_{CW}}-1}{Y_{CW}} \quad \text{when} \quad 1-p-\frac{Y_{CW}}{2}p^2 = 0$$

At this point it is possible to compare this result to those obtained under DK preferences with direct reciprocity, $(1-p) \geq p+Y_{CW}(p^2-\frac{p}{2})$. It is worth considering the question of which has the higher p^{max}. Recall that p^{max-dk} was obtained from the condition, $(1-p) \geq Y_{CF}(p^2-\frac{p}{2})$, while p^{max-ir} is obtained from the condition, $1-p \geq Y_{CW}\frac{p^2}{2}$. Observe that for both the LHS are the same and so it is most insightful to study each RHS and compare. The only way that the p^{max-ir} would be bigger is if at some point the graphs cross. Setting the two RHS equal to each other and simplifying gives the equality: $p^2 = p$, which means that the lines only cross at the endpoints. Looking at the second one, $Y_{CW}(p^2-\frac{p}{2})$ and differentiating with respect to p obtains a critical point at $p = \frac{1}{4}$ with second derivative everywhere positive so the original function is concave up and this is a minimum. So the first graph is everywhere lower than the second and must intersect the line $(1-p)$ at a larger p. Therefore the p^{max-dk} is indeed the larger of the two. This means that the consumer is better off with preferences for indirect reciprocity while the worker does no better or worse. Figure 2 illustrates these circumstances.

Proposition 4 Assuming $(i'_a), (i'_b), (i'_c)$ and (ii'), and consumer endowed with preferences for indirect reciprocity inspired by DK (2004), with ϕ unobserved: in any equilibrium the firm will offer $(1, p^{max-ir})$ and the consumer will use the strategy $q(p) = 1$ for any $p \leq p^{max-ir}$ and $q(p) = 0$ for any $p > p^{max-ir}$.

Proof: The firm cares to maximize profit and does this by obtaining the highest possible ϕ and p. It knows that the consumer is uninformed of the value ϕ and therefore has incentive to keep it as high as possible which is, $\phi = 1$. Examining the consumer's decision between $q(p) = 1$ and $q(p) = 0$ results in the following inequality: $(1-p) \geq Y_{CW}\frac{p^2}{2}$. To complete the proof observe the condition for the inequality to hold: $Y_{CW} \geq \frac{2(1-p)}{p^2}$, and note that the firm chooses the price that forces equality, p^{max-ir}.

It now worthwhile to pause and consider what has been shown. Here the pos-

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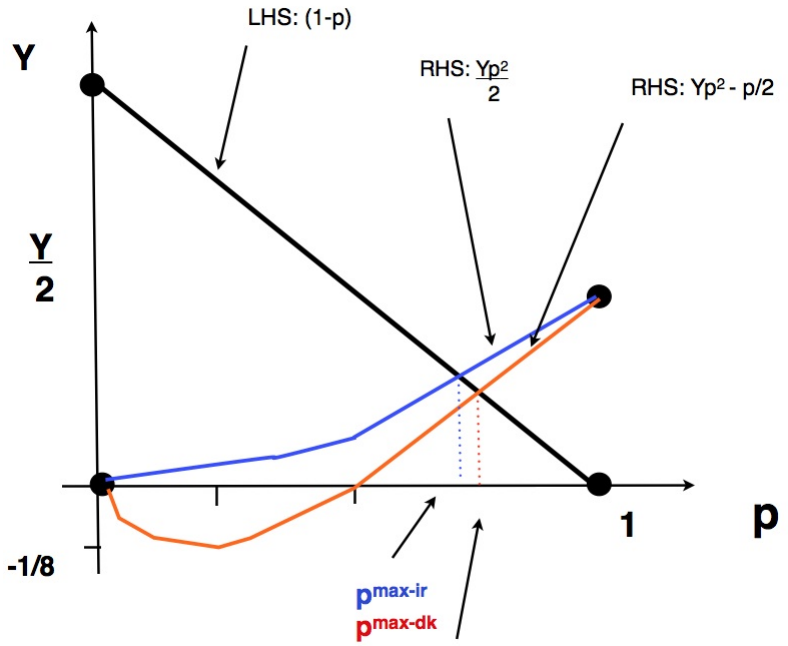
Figure 2.2: Profit maximizing price is greater with DK(2004) preferences.



sibility of an advertising campaign that has shifted consumer concern toward the worker has been considered. It has then been demonstrated that while the consumer now has concern for the firm's treatment of the worker but does not observe the actual labor conditions, ϕ, only the consumer will benefit. Consumer preferences for indirect reciprocity are insufficient to alleviate sweatshop conditions. This is because while the firm lowers the price below those seen under classic preferences or DK(2004) preferences it still keeps $\phi = 1$. The consumer might be troubled by the existence of sweatshop conditions but is unable to help given that it is impossible to verify if the firm is indeed operating a sweatshop. Since the consumer cannot verify actual conditions the firm has no incentive to improve them. It turns out that the consumer gets a better deal due to lower prices here than under DK (2004) preferences and under the classical solution. Further this actually lowers the maximum potential the worker could obtain should the firm ever decide to lower ϕ.

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2.4.2 Transparency of Sweatshop Conditions: ϕ Observed

In this section the game considered involves a consumer with preferences for indirect reciprocity and with the possibility of increased concern for the worker through Y_{CW}. Also here the consumer is actually informed about what the sweatshop conditions are like. In the previous section it was discovered that a campaign alone is unlikely to improve the worker's situation given the firm is incentivized to maintain $\phi = 1$. Now continuing with the analysis of the game under consumer preferences for indirect reciprocity, the paper will now consider the condition where ϕ is observable to investigate if transparency regarding worker treatment will improve the situation. As before the consumer will use $q(\cdot) = 1$ when the following inequality holds and $q(\cdot) = 0$ otherwise: $1 - p + Y_{CW}(\phi p)(\frac{p}{2} - \phi p) \geq 0$.

Conceivably in order to benefit the worker it will need to be the case that the consumer will accept a tradeoff of higher prices for lower ϕ's. A preliminary examination of the inequality is useful in order to gain some insight into the problem. Essentially one wishes to ask the following question: Is it possible that for a given profit level prices may be increased (while ϕ decreased to maintain constant profit) while the inequality holds? To answer the question one can differentiate with respect to price : $-1 + \frac{Y_{CW}}{2}(\phi p)$. Note that this is positive for adequate Y_{CW}. This provides some intuition to support the claim that the firm may reduce ϕ and be able to compensate through raising prices. It is possible to examine more precisely what will happen here.

Despite the fact that ϕ is now observable, the firm certainly still retains the option of offering $\phi = 1$. Should this occur, the analysis is identical to that of the unobservable case described in Proposition 4. In that case the maximum price that the consumer will pay is a solution to the quadratic found earlier, $\frac{-Y_{CW}}{2}p^2 - p + 1 = 0$. It is also possible to consider the other extreme, that is, where the firm offers $p = 1$. Plugging this into the consumer's inequality and solving produces the condition $0 \geq Y_{CW}\phi(\frac{1}{2} - \phi)$. So when $p = 1$, the consumer will buy $q(\cdot) = 1$ when $\phi \leq \frac{1}{2}$. Of course under this circumstance a profit maximizing firm offers $\phi = \frac{1}{2}$ and obtains

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profit of $\frac{1}{2}$. This is true for all consumers so the firm is assured of a profit of at least one half as long as it uses $\phi = \frac{1}{2}$. It is interesting to consider under what circumstances the firm does better. It is possible to compare the profits that arise from this offer against the profit that arises when ϕ is unobserved. This accomplished by the inequality, $\frac{-Y_{CW}}{2}p^2 - p + 1 \geq \frac{1}{2}$, which demonstrates that the profit the firm earns from $(\phi = 1, p = p^{max-ir})$ exceeds the profit earned from $(\phi = \frac{1}{2}, p = 1)$ when $Y_{CW} \leq 4$. With this result it is possible to state a proposition regarding consumer behavior in equilibrium.

Proposition 5 Assuming $(i'_a), (i'_b), (i'_c)$ and (ii'), and that the consumer is endowed with preferences for indirect reciprocity inspired by DK (2004) while ϕ observed the firm will make the offer which maximizes profit, $(\phi^{max-ir}, p^{max-ir})$, and the following consumer behavior will be observed in equilibrium:

- (i): All consumers will use $q(\cdot) = 1$ when the firm offers $(\frac{1}{2}, \cdot)$; actually any $\phi \leq \frac{1}{2}$.
- (ii): If $Y_{CW} < 4$ the consumer will use $q(\cdot) = 1$ for offers in which $(\phi \leq \phi^{max-ir}, p \leq p^{max-ir})$. When $\phi = 1$ this $p^{max-ir} > \frac{1}{2}$.
- (iii): If $Y_{CW} = 4$ the consumer will use $q(\cdot) = 1$ when the firm makes any offer yielding profit of $\frac{1}{2}$. The consumer uses $q(\cdot) = 0$ for any offer with $\phi p > \frac{1}{2}$.
- (iv): If $Y_{CW} > 4$ the consumer will use $q(\cdot) = 1$ for any offer in which $(1, p^{max-ir} < \frac{1}{2})$ and use $q(\cdot) = 0$ for any offer with $(1, p \geq \frac{1}{2})$; with the exception of (i).

Proof:

- (i): Observe the inequality $1 - p + Y_{CW}(\phi p)(\frac{p}{2} - \phi p) \geq 0$ which must hold in order for any consumer to use $q(\cdot) = 1$. This boils down to the requirement that $\phi \leq \frac{1}{2}$.
- (ii): In order for any consumer to use $q(\cdot) = 1$ it must be the case that $1 - p \geq Y_{CW}(-\phi p)(\frac{p}{2} - \phi p)$. This is satisfied when $Y_{CW} \leq \frac{1-p}{(\phi p)(\phi p - \frac{p}{2})}$ and holds

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with equality at $\phi = \phi^{max-ir}$ and $p = p^{max}$. Suppose $\phi = 1$ while $Y_{CW} < 4$. Then this inequality amounts to $4 \leq \frac{2(1-p)}{p^2}$ or the quadratic $1-p-\frac{Y_{CW}}{2}p^2 = 0$. Using the quadratic formula if $Y_{CW} = 4$ the resulting p^{max-ir} is one half. But here it is assumed that $Y_{CW} < 4$; moreover since p^{max-ir} is decreasing in Y_{CW} together this implies $p^{max-ir} > \frac{1}{2}$. In fact the value of p^{max-ir} nears a maximum of 1 in the limit when $Y_{CW} \to 0$. When the effect of reciprocity diminishes the result approaches the classical solution. Relative to the offer $(1, p^{max-ir})$, does the firm do any better trading off lower ϕ for higher p? Since the firm is able to get profit of at least p^{max-ir} which comes from $(1, p^{max-ir})$ suppose profit is kept constant at this level. Then $1 - p + Y_{CW}(p^{max-ir})(\frac{p}{2} - p^{max-ir}) \geq 0$. What happens when p rises and profit stays at p^{max-ir}? Well, differentiating with respect to price yields $-1 + \frac{Y_{CW}p^{max-ir}}{2}$ the RHS of the sum is a constant no larger than two that is multiplied by its respective maximum price/profit. This derivative is negative for any $Y_{CW} < 4$ and $p^{max-ir} > \frac{1}{2}$, so the consumer will use $q(\cdot) = 0$ for any price higher than p^{max-ir} and the firm cannot benefit from using $\phi < 1$.

- (iii): Suppose the firm makes an offer of the sort $(1, p^{max-ir})$. Then the consumer will use $q(\cdot) = 1$ when the following inequality holds: $(1 - p) \geq 4(-\phi p)(\frac{p}{2} - p)$. Solving leads to the quadratic: $0 \geq 2p^2 + p - 1$ and so $p^{max-ir} = \frac{1}{2}$ which is where it holds with equality. Also, from (i) it is clear the consumer will use $q(\cdot) = 1$ when the firm offers $(\frac{1}{2}, 1)$. Suppose now that the firm holds profit at constant value of one half and seeks to lower price while increasing ϕ. This leads to the inequality: $1 - p + 4(\frac{1}{2})(\frac{p}{2} - \frac{1}{2}) \geq 0$ which boils down to $1 - p + p - 1 \geq 0$ which of course holds for all prices. So the consumer buys $q(\cdot) = 1$ for any offer (ϕ, p) such that $\phi p = \frac{1}{2}$. For the second part suppose profit is equal to $\frac{1}{2} + \epsilon$ for small $\epsilon > 0$. Then the condition for the consumer to use $q(\cdot) = 1$ is the inequality: $1-p+4(\frac{1}{2}+\epsilon)(\frac{p}{2}-\frac{1}{2}-\epsilon) \geq 0$ which can be rewritten as: $1 - p + 2(\frac{p-1}{2} - \epsilon) + (4\epsilon)(\frac{p-1}{2} - \epsilon) \geq 0$. This condition never holds. At the extreme values when $p = 1$ the LHS is $-2\epsilon + -4\epsilon^2 < 0$

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and when $p = 0$ the LHS is $1 + (-1 - \epsilon) + -2\epsilon - \epsilon < 0$.

- (iv): Examine what happens when the firm offers $(1, p)$. The consumer uses $q(\cdot) = 1$ in response when the inequality holds: $1 - p \geq Y_{CW}(-\phi p)(\frac{p}{2} - \phi p)$. This can be rearranged to obtain the quadratic, $-\frac{Y_{CW}}{2}p^2 - p + 1$, which is solved to find this p^{max-ir}. Referring to the quadratic formula: $\frac{1-\sqrt{1+2Y_{CW}}}{-Y_{CW}}$. When $Y_{CW} = 4$, $p^{max-ir} = \frac{1}{2}$. But here it is assumed that $Y_{CW} > 4$ and p^{max-ir} is decreasing in Y so it must be that $p^{max-ir} < \frac{1}{2}$ if the consumer is going to buy.

From these results it is seen that the firm achieves the highest profit when the consumer has $Y_{CW} < 4$, occuring with the offer $(1, p^{max-ir})$. A consumer with $Y_{CW} < 4$ has no desire to trade higher prices for lower ϕ. This corresponds to the consumer that is informed of the sweatshop conditions but is not concerned enough to help the worker. When the consumer has $Y \geq 4$ the best the firm can do is a profit of one half and when the consumer has $Y_{CW} > 4$ this may only be achieved with the offer $(\frac{1}{2}, 1)$. Consumers with $Y_{CW} \geq 4$ are willing to trade monetary value for psychological payoff as they accept higher prices (up to full price) in order to see to it that the worker receives better compensation. This corresponds to the consumer who is aware of the sweatshop conditions and is concerned enough to respond negatively toward to the firm if conditions are not improved even at a cost to the consumer's own share of surplus. Under these circumstances where the consumer has preferences for indirect reciprocity on behalf of the worker and is actually informed about the working conditions it is possible that the profit maximizing firm will improve the sweatshop conditions.

2.5 Discussion

The first game considered gave all players standard preferences. The classical analysis here lead to the unique subgame perfect equilibrium in which the firm captures the entire surplus and the worker is fully exploited. This corresponds to the default

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situation in which the consumer may or may not be aware that the firm operates a sweatshop and does not care either way.

The second game allowed the consumer to be endowed with DK (2004) preferences. Here given the specification of the model it might have been the case that this would be enough to benefit the worker. After all, it seems reasonable that the firm might lower ϕ in order to undermine the consumer's ability to respond with negative reciprocity thereby helping the worker as a by-product of the firm's strategic behavior. It turns out that when the consumer's perception of the firm's kindness is dependent on his own treatment reciprocity preferences are not enough to help out the worker. This result holds whether or not the consumer observes the worker's treatment. The consumer benefits here relative to the classic solution since now the firm must offer a price strictly lower than one. The worker is still exploited but the consumer gains a share of the surplus. When the consumer is able to observe the sweatshop conditions this corresponds to the case in which there are media reports or disclosure by the firm.

The third game allowed the consumer to be endowed with preferences for indirect reciprocity inspired by DK (2004). This means that the focus of the consumer has shifted to the worker and so the firm is regarded as kind insofar as its treatment of the worker is favorable irrespective of treatment of consumer. When the consumer has these preferences but is unable to observe the treatment this is enough only to benefit the consumer himself. The worker is still exploited and the consumer actually benefits from a greater share of the surplus than even under DK (2004) preferences. This corresponds to the case in which the consumer may even care a great deal about the fact that the worker may be subject to sweatshop conditions, but is unable to verify whether this is actually the case.

It is then shown that when the consumer does observe the labor conditions, the worker is actually able to benefit. At this point it is possible that the worker will no longer be exploited as the consumer trades off its own share of the surplus to the firm in exchange for better labor conditions for the worker. This corresponds to the situation in which both advertisement campaigns have raised consumer awareness

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perhaps enhancing the degree to which consumers are motivated to respond to the firm due to reciprocity, and to where the consumer actually is able to have information regarding the actual sweatshop conditions perhaps due to investigative journalism or disclosure by the firm itself. A main conclusion is that in order to alleviate working conditions it is necessary to have both a campaign to turn the consumers attention toward the worker and some policy for transparency or disclosure regarding the actual sweatshop conditions.

2.6 Conclusion

The findings from this paper provide some insight into the issues that were considered at the outset and may guide those wishing to improve sweatshop conditions by educati ng consumers. It was wondered whether consumer awareness of the actual treatment and concern for the workers were necessary for consumer behavior to influence the firm to improve working conditions. Indeed both are important and from the results the best recommendation to groups interested in advocacy for improved conditions is to combine these in their efforts. It is important for the primary concern of the individual consumer to be shifted away from one's own treatment by the firm in terms of favorable prices, and toward the firm's treatment of the worker in terms of better labor conditions. However, this alone is not enough. Additionally this focus needs to be directed to specific examples as consumers need to know about the working conditions when considering their purchases. When the conditions of the paper are met consumers will respond with negative reciprocity and refuse to buy from firms using sweatshop labor. In fact, some actual anti-sweatshop organizations do this. Among the goals of the Clean Clothes Campaign's Better Bargain initiative that focuses on large retailers are two that can be directly supported by the results of this paper.[6] These goals are for increased transparency in terms of identifying suppliers and efforts for improving conditions, and to encourage

[6]The Clean Clothes Campaign is an alliance of advocacy groups and unions in Europe that seeks to improve labor conditions for workers in garment factories around the world.

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consumers to consider workers' rights.[7]

There is another side of at least equal importance to consider when taking guidance from the results in the paper. The paper certainly shows that sufficiently motivated consumers will not buy when the worker is treated poorly. However, it also shows that such a consumer is willing to trade material payoff for psychological well being to the extent that this consumer is willing to actually pay a price premium to buy when the worker is treated better, as if subsidizing the wage. This finding and application is consistent with the empirical findings of Hiscox & Smyth (2005) and Rode, Hogarth, & Le Menestrel (2008) and suggests that items labeled as 'sweatshop-free' will be purchased by these consumers at high rates. Such labels are likely effective at least in part due to lighter information burdens on an individual concerned consumer as even with the benefit of reports from anti-sweatshop advocates it is far easier to simply view a no-sweatshop label than to try to determine which items were produced by sweatshops. The results about when consumers buy and not buy can be taken together to provide a guide for a more comprehensive program. If one cares about alleviating sweatshop conditions most likely some combination of these recommendations is the most beneficial: getting consumer to care, getting consumers to know who operates sweatshops, and letting them know which products are sweatshop free.

[7]http://www.cleanclothes.org/campaigns/what-we-want-to-achieve; accessed 11.29.11 posted on website 2.25.09.

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CHAPTER 3

EXPERIMENT ASSOCIATIONS AND THE DIFFUSION OF AGRICULTURAL INNOVATIONS

3.1 Introduction

Innovation has the potential to increase productivity and lead to economic growth, however, these gains cannot be fully realized if the technological advancements are unable to reach those who ought to implement them. Efficient diffusion of technology requires potential adopters to know that the innovation exists and to have the ability to gain access. Further, to the extent that people prefer known quantities, it may be advantageous for these potential adopters first to observe the experience of others in order to make wiser decisions themselves. Not only can local trials of a new innovation benefit adopters, but they can be a vital source of information for researchers as well. This is especially true if the success of the new technology varies with characteristics unique to the location, as is the case with agricultural technology, or if its value depends on idiosyncratic features of users or usage patterns that cannot easily be recreated in the laboratory. In these cases it can be beneficial for researchers to receive reports from trial runs by early adopters. Researchers with access to feedback on the performance of the product during the development phase can then make minor adjustments to improve the final version. One way in which these aims can be accomplished is by directing the innovation to diffuse initially through a network of folks familiar with the new technology who can both communicate with the researchers and also advertise its merits to other potential adopters. Good examples of such networks are the experiment associations comprised of scientifically literate farmers who cooperated with agricultural experiment stations to test and disseminate biological and non-biological innovations. Among the earliest were the Ontario Agricultural and Experimental Union (OAEU) and

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the Wisconsin Agricultural Experiment Association (WAEA), which was modeled after its Canadian predecessor.

Economic historians have rarely been able to trace the information flow that leads to the diffusion of technology. In this paper I seek to make a contribution by studying the OAEU and WAEA to better understand their role in facilitating the transmission of innovations from the agricultural college and experiment stations to ordinary farmers. The central purpose of each organization was to improve the agricultural productivity of their respective regions and through my empirical analysis I investigate the extent to which each was successful. I observe the locations of experimenting members and argue that the presence of experimenting members benefited farmers within a county by assisting the researchers in directing particular varieties to the region, by helping farmers make better decisions about what varieties to plant having observed others in their community, and by making available improved varieties for purchase by farmers from known sources. I examine whether counties with greater numbers of experimenters saw higher crop productivity as measured by yield per acre in the crops those experimenters tested. The results of the paper illuminate the mechanism of diffusion. For the OAEU there is a slightly delayed, positive, and statistically significant effect on the productivity of oats and peas. Findings for the WAEA show an immediate, positive and statistically significant effect on the productivity of oats and barley. Taken together the results provide evidence that these experiment associations were each an effective means for rapid technology diffusion.

3.2 Related Literature

There is already a large literature concerning the diffusion of agricultural technology more generally. Griliches (1957) describes the S-shaped pattern of adoption seen in the diffusion of hybrid corn; Griliches (1960) associated the decision to adopt, and the rates at which this occurred, with the profitability of hybrid corn in one's region. Here there is also an observation about the resistance of farmers to accept new hybrid

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seed corn which was in part due to a reluctance to trust researchers especially in light of the large upfront investment required to use the seed. One of the motivations for farmer experiment associations was to overcome this mistrust of new technology by allowing farmers access to it through their peers. More recently, Sutch (2008) provides evidence that adoption of hybrid corn was driven by effective advertising rather than by a clear yield advantage over other varieties and mentions anecdotally that sometimes hybrid corn seed was provided to farmers to allow them to conduct their own comparison trials for demonstration to themselves and their neighbors. A very similar process underlies part of the mechanism of diffusion from experiment stations to farmers through the OAEU and WAEA as one of their objectives was to spread knowledge through demonstration.

There has also been much work studying the role of the experiment station in the development and diffusion of agricultural technology. Olmstead & Rhode (2008) provide extensive evidence for the ways in which agriculture in the United States was changing both in thought and in practice, and discuss the extent to which these innovations affected productivity. They describe the efforts of the experiment stations to test new varieties and the eventual adoption by farmers and they explain the role of improved varieties in extending the crops into new regions, primarily northward and westward. Most relevant to my paper is their work discussing biological innovations in the wheat and corn crops and I contribute to the understanding of one mechanism supporting the diffusion they document. Regarding the wheat crop they show that biological innovations were largely responsible for preventing significant crop losses in the face of disease, pests, weeds, and climate conditions. With respect to the corn crop they demonstrate how the process of innovation led to varieties designed to suit specific counties. It is this sort of process for the optimal selection of varieties that the OAEU attempted to facilitate, albeit with different crops. Perhaps closest to my paper is work by Kantor & Whalley (2012) which is interested in the effects university research conducted through experiment stations had on agriculture. I take a much narrower focus and with the OAEU and WAEA study one specific path through which innovations originating at the experiment station reached ordinary

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farmers. From my work it is possible to learn something about a particular means through which diffusion of innovation and research spillovers occurred.

There is also research documenting the factors affecting individual adoption decisions. Conley & Udry (2010) investigates the role of social learning in the patterns for diffusion of non-biological innovation through networks of pineapple farmers in Ghana. Their model and empirical analysis demonstrate the effects of a farmer's experience on the behavior of others within the network. They also find evidence that inexperienced farmers are more responsive to the successes and failures of others. Duflo, Kremer, & Robinson (2011) provide an example of a program that can work to improve the diffusion of technology sold by a private company. They consider fertilizer usage by farmers in Kenya and note that a major hinderance to adoption is its price, however, due to enormous returns to applying fertilizer it would more than pay for itself if one could overcome the initial obstacle. Their findings suggest that small subsidies strategically offered around harvest rather than during other times lead to higher adoption rates than larger subsidies away from the harvest season. A contribution of my paper is to study how experiment stations handle diffusion of their innovations and to analyze the structure of this mechanism. In order to encourage rapid dissemination without concern for maintaining property rights over the innovations, improved varieties were provided to experimenters for free. After testing had shown success in the region the seed was then to be distributed to other farmers at modest prices in light of the fact that these were government funded entities.

Finally, part of the purpose of the OAEU and WAEA was to educate farmers about the benefits of implementing the innovations developed at the experiment stations and agricultural college. Parman (2009) considers the agricultural innovations of the early twentieth century, their subsequent diffusion, and the role of human capital. In particular he estimates the spillover effects of public schooling on agricultural productivity in Iowa during this time period and finds a positive effect. In my paper I am in part picking up the effect due to the educational efforts of these organizations by including a measure for the number of experimenters within

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a county. For the OAEU, however, I am unable to disentangle the education and seed dissemination effects. For the WAEA I am able to separate the effects of seed growers and ordinary members who most likely spread information rather than seed during that particular year. However, I find no evidence of an effect through the latter channel.

3.3 Experiment Associations Background

In the mid to late nineteenth century there were big changes occurring in North American agriculture that would eventually lead to technological advancements that would forever transform the practice of farming. In the United States the Morrill Act of 1862 had led to the establishment of agricultural colleges and with the Hatch Act of 1887 came the rise of the experiment station. In Canada the first agricultural college had opened in Quebec in 1859 and the Ontario Agricultural College and Experimental Farm was established in Guelph, Ontario in 1874. It began a program of experimental work two years later. These developments signaled the beginning of an institutionalized shift to a more systematic and academic approach to farming; agriculture was becoming a science in the truest sense complete with controlled laboratories and a research program. Although enrollments were generally low by today's standards it was certainly possible for young farmers to come to the agricultural college to learn the latest techniques. While the work of the agricultural colleges and experiment stations undoubtedly increased the amount of knowledge and led to the availability of improved crop varieties, it was not clear that the spillovers would necessarily be fully realized by ordinary farmers. That farmers would be eager to adopt the new technology based on the work of the stations was by no means a forgone conclusion; nor was it clear that the innovations derived through the work of the agricultural college would be effective in regions distant from the agricultural college. Farmer experiment associations were created in part to address concerns such as these and had the advantage of essentially allowing researchers to have laboratory space in members' fields while giving farmers access

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to the experiment stations' latest innovations. Two such organizations will receive special attention in my paper, the Ontario Agricultural and Experimental Union (OAEU) and the Wisconsin Agricultural Experiment Association (WAEA). Both organizations were comprised of farmers who had received some formal training in agriculture, usually at the agricultural college. This was by design as researchers needed to be confident in the organization's ability to perform experiments. The general structure allowed for a systematic program of further testing of promising biological and non-biological innovations that had been developed through the research conducted by college and experiment station officials. The role of the experimenter was therefore to report the results to the researcher and to transmit the innovation to others in their community. The latter was to be done with a sort of evangelical fervor and there is anecdotal evidence suggesting this actually was the case.[1]

During this time period farmer associations were by no means a rarity. In the United States and Canada dairy producing areas had large, active associations for dairy farmers. The states of New York, Oregon, Minnesota, Texas, Alabama, and Illinois had experiment or seed growing associations of one sort or another during the time period I focus on. However, what set apart the OAEU and WAEA from most of the others was their structure and objectives. For these reasons I focus on these two organizations in particular. Created in Guelph, Ontario in 1879, to the best of my knowledge the OAEU was the first of its kind. In 1901 the WAEA was formed in Madison, Wisconsin and was patterned after the Canadian organization. Both shared important characteristics that made them unique for their time. First, each had a criteria for participation that included a level of scientific knowledge often based on formal training at the agriculture college. Second, each had the goal of conducting controlled experiments across their respective regions to continue research begun at the agricultural college to determine the optimal varieties and methods of cultivation for each area. This was important so that officials could determine

[1]In the comments section of the OAEU Annual Report for 1899, J.E. Frith of Oxford County proclaims,"The experiment actually became the leading topic of the village talk."

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which particular varieties should be directed to each county or district. Third, each had the goal of educating farmers so they might be more willing to adopt innovations from the agricultural college. Fourth, each had the goal of making improved varieties of seed available to ordinary farmers from those in their community. Both organizations were designed with the purpose of testing and disseminating biological and non-biological innovations and structured to allow diffusion to occur as fast as possible.

While the two organizations were otherwise quite similar, it is worth observing that there were differences. The OAEU placed a higher emphasis on uniform, controlled experiments and conducted trials with many varieties, seeking to educate farmers to make wise decisions regarding their seed acquisition. The WAEA was concerned more with the eventual dissemination of purebred seed and tested fewer varieties while working toward the goal of increasing the quantity of seed in order to distribute the improved varieties directly to farmers. Nevertheless in both the OAEU and the WAEA the researchers at the respective agricultural colleges were able to gain insights into their varieties from the results. This was probably a larger advantage in Ontario. Also, at the other end of the arrow of information flow, both organizations held similar benefits for participating experimenters and other farmers. In both cases experimenters were given access to the latest knowledge and best varieties earlier than non-participants. While in year t each experimenter would not have enough seed to plant their entire field, by year $t+1$ not only would seed be available, but so would knowledge about whether or not that variety was actually successful in their locality. In either case farmers were able to scale up their production of the variety for their own use and to sell to others. This was probably a larger advantage in Wisconsin where experimenters were to eventually become distributors of the particular variety they were testing. To the best of my knowledge the OAEU and WAEA were responsible for controlling the diffusion of all of the improved varieties developed at their respective experiment stations. Finally, the presence of a test in an area had the potential to lead to knowledge spillovers as nearby farmers were able to witness the results and learn about the specific innovation from the

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experimenter.

3.3.1 Ontario Agricultural and Experimental Union

The OAEU was formed by a group of college officials, students, and former students in 1879. The first experiments conducted through the organization were in 1886 and involved twelve members. Prior to that point the OAEU's biggest function was meeting annually at the Ontario Agricultural College (OAC). I am most interested in the activity of the OAEU from 1892-1899 which approximately coincides with the first years of testing crop varieties. Earlier experiments had mainly concerned the use of fertilizers or other cultivation techniques. During this time and for several decades afterwards the fellow in charge of the field crop experiments was Charles Ambrose Zavitz, himself an 1888 graduate of the Ontario Agricultural College. Originally the bylaws of the organization allowed only for paid members to receive experimental materials. However, the constraint was never binding since it was removed in 1886. Even so, scientific literacy was certainly important to ensure experimenters understood what they were doing to the extent necessary to conduct the experiment and therefore priority was given to paid members and to those who the OAEU believed could perform the experiments correctly.

From rather sparse beginnings the number of farmers conducting experiments through the OAEU grew steadily until early in the next decade when it expanded more rapidly. Some of the rapid expansion is attributable to its strategic recruitment efforts. For instance, in 1891 county secretaries were asked to provide names and mailing addresses of all former OAC students in each township, and in the event that there were not least two, they were to nominate other farmers for participation. As a result, the OAEU was able to send a recruitment letter to around 800 farmers for that season. The recruitment efforts were successful and soon the number of experimenters greatly exceeded paid membership. Members of the OAEU initially paid a fee of $0.50 annually which rose to $1.00, but this was not a necessary condition for taking part in experiments. Therefore additional funds beyond annual dues were required to cover the costs of sending materials for each trial. To help

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it achieve its purpose the organization began receiving a government grant in the amount of $75 per year beginning in 1888. This amount was increased annually to allow the organization to accommodate growing numbers of experimenters. The total expenditure on experiments on field crops from 1886-1901 was $7528.20, (Zavitz 1903).

As membership grew, so did the scope of its activities. Eventually experiments encompassed many areas of agriculture outside of the study of field crops to include dairy, apiculture, and forestry among many others. My focus is on the activities of the OAEU with field crops and in particular concerning oats, peas, wheat, corn, and barley. Table 1 below displays these crops by acreage and shows the number of varieties that had been experimented upon at the Ontario Agricultural College and the number of varieties distributed throughout the province.[2]

Table 3.1: Significance of Field Crops in Ontario and Prominence with OAEU

Crops	Acreage, 1898	OAC Varieties since 1886	OAEU Varieties, 1898
Hay and clover:	2,453,503	71	9
Oats:	2,736,360	210	5
Winter wheat:	1,048,183	148	7
Peas:	865,951	100	5
Corn	520,696	219	6
Barley:	438,784	94	4
Spring wheat:	389,205	144	3
Potatoes:	169,946	236	6
Rye:	165,089	6	1
Turnips:	151,601	179	4
Buckwheat:	150,394	6	3
Mangels:	47,923	102	4
Beans:	45,220	41	3
Carrots:	12,418	60	5

The process of cooperative experimentation went as follows. After a period of trials at the Experimental Farm, often 3-5 years, the best performing varieties

[2]Table 1 essentially reproduces the table found on pg. 15 of the 1898 annual report of the OAEU.

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were selected for cooperative experiments and the poorest varieties were discontinued. As an example, during the 1894 season 80 varieties of oats were tested. Of these researchers decided to continue working with 17 varieties through cooperative experiments, (Zavitz 1894). According to (Zavitz 1903), the preparation for the experiments was tremendous. With the successful varieties identified, a committee would determine what experiments would be conducted and would then work to assemble materials and instructions. These experiments were designed to meet the criteria of being valuable both to the researchers at the Ontario Agricultural College and to the participating farmers themselves and to accomplish both they had to be feasible for experimenters to operate. Experimenters were to follow a strict protocol including specific dimensions of the plot to be used and were to report complete results back to the OAEU on a form that had been provided. Part of the purpose of the cooperative experiments was to spread information about the innovations being tested and so directly stated in the instructions was the imperative command to invite one's neighbors to observe the experiment, discuss it with friends, and mention it in the local newspaper (Zavitz 1903).[3]

With the preparation complete, each spring the OAEU mailed out a description of the experiments available that year and interested farmers returned the form indicating their top two choices. In addition to the preference indicated by one's response to the recruitment letter the materials for each experiment were distributed according to the following order of priority: first to official members who had paid their fee, then to experimenters who had participated the past year and done satisfactory work, then to other farmers whose participation had been recommended by officials from farmers' institutes, agricultural societies, agricultural colleges, or the public schools, and finally to those who had learned about the experiments and were interested, (Zavitz 1903). As an example of the magnitude of the recruitment efforts and response rate, in 1892 the recruitment letter had been sent to 1,500 folks and 754 participated in experiments. Nevertheless, relative to the stock of experi-

[3]Based on the reports received, Zavitz claimed that in 1902 at least 25,000 people had seen the cooperative experiments with oats.

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ment materials typically there was excess demand because there was not always the financial resources provided for all of those who were willing to participate.

According to Zavitz, only reports that had been filled out completely and correctly would be counted as satisfactory. These are the experimenters that I am able to observe. Also I generally do not observe non-experimenting members during the relevant period. Even minor deficiencies was sufficient for excluding a report as unsatisfactory. Because the OAEU only reported results of satisfactory experiments in its annual reports, and not of all experiments that had taken place, it is unclear how many total experiments were performed on field crops in a given year, nor is it clear what share of those conducting experiments had no other affiliation with the Ontario Agricultural College and were otherwise ordinary farmers, albeit scientifically inclined. At best my results can say something concrete about the effectiveness of *successful* experimenters.

Table 3.2: Summary of OAEU Agriculture Experiments 1891-1899

Year:	1891	1892	1893	1894	1895	1896	1897	1898	1899
Experiments:	12	12	13	14	15	16	18	19	23
Experimenters:	203	754	1,204	1,440	1,699	2,260	2,835	3,028	3,485
Satisfactory Reports:	126	295	416	504	513	501	610	667	739

Any effect the OAEU had probably came through the following means. With the benefit of having results from trials across the province, researchers at the experimental farm were in a much better position to assess the potential of particular varieties. Further, to the extent that the experimenters were successful in sharing knowledge of their experience with others, nearby farmers would have a better idea of which variety would be best for their own fields. Experimenters were generally allowed to keep the seed and crop produced through the trials and were encouraged to sell the seed to their neighbors. In this way those in the community would have access to the successful varieties the following year.

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3.3.2 Wisconsin Agricultural Experiment Association

In 1848 Wisconsin gained statehood and its flagship university was founded in Madison. In 1883, four years prior to the federal Hatch Act, the Wisconsin state legislature provided for the creation of an experiment station to work in conjunction with the existing University Farm. In 1905 additional station branches opened in the northern regions of the state to create laboratory conditions more relevant to those areas. The primary means of information diffusion in the state at this time were annual reports and other bulletins. In addition there were Farmer's Institutes that had been held across the state beginning in 1885 and the Wisconsin College of Agriculture's Short Course in Agriculture that was started in 1895. The course was geared toward young farmers who could come to study in Madison for a short period of time in order to quickly learn practical applications of the knowledge developed through research at the stations. The WAEA was formed in 1901 with 187 members, many of whom would cooperate to test and disseminate both biological and non-biological innovations originating from the Experiment Station. By 1908 there were over 1,500 members of the organization. Examples of their activities include selecting the best varieties of seed to plant in the state and determining the optimal formaldehyde solution to deal with smut affecting oats and barley. I focus on their work with oats, corn, and barley because these three crops not only comprised the majority of the experimental activity but were important to the state. I am most interested in its activity from 1903-1911 which coincides with the first years of activity with these crop varieties. R.A. Moore, a professor of agronomy at the University of Wisconsin, oversaw the field crops branch of experimentation for the WAEA.

To become a member one must have attended a Short Course or have had some equivalent formal training in agriculture at a county school or another agricultural college as well as pay $0.50 in annual dues. As in Ontario the reason for the strict membership requirement was to ensure that experimenters would have a certain level of scientific literacy that could be relied upon by station researchers. Unlike in

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Table 3.3: Significance of Field Crops in Wisconsin

Crops	Acreage, 1906
Oats:	2,072,381
Corn	1,315,724
Barley:	712,845
Rye:	306,460
Wheat:	213,754
Potatoes:	222,447

the OAEU, this membership requirement was generally not relaxed. However others could be admitted into the organization as honorary members by way of majority vote at the annual meeting and therefore become eligible to conduct official WAEA cooperative trials. The WAEA began receiving a grant from the state legislature in 1903 of $1000. State funding from this same act also covered the cost of distributing 5,000 copies of the organization's annual report which published findings from the experiments and lists of those with seed for distribution that year.

The experimentation and dissemination process of the WAEA began at the Experiment Station where researchers would isolate a particular promising variety. Once the station had grown enough seed of that variety, it would be distributed to members for acre sized trials. Those receiving seed and conducting experiments were then to report the results of their tests back to the station so that the results would be compiled, analyzed, and published in the annual bulletin of the WAEA. As with the OAEU, quite often the number of reports the WAEA counted was smaller than the total number of experiments from that season. It is unclear whether the WAEA ever tossed out submissions, but it seems in many cases this gap was due to experimenters failing to submit their report altogether. Sometimes the annual report of the WAEA would provide numbers of experiments conducted, numbers of reports received, and numbers of good results but none of these measures identified particular members. As far as members, what I actually observe from the WAEA is a list for each year without mention of their involvement with particular experiments.

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In each annual report the WAEA also published a list of seed grain growers in order to help farmers find those nearby from whom they could obtain the improved seed for the upcoming season. The 1905 WAEA Seed Grain Growers list is prefaced by the following statement, "Members of the Experiment Association are rapidly becoming the seed growers of the state, and by systematic selection of seed and care in culture and curing of the crop, produce a fine grade of pure-bred seed grains. These seed grains are sold by the producer either in small or large quantities, at reasonable rates." Ordinary farmers inquiring at the experiment station or agricultural college for seed were directed to the experimenting member located nearest to them. Experimenters were therefore able to sell the seed to their neighbors and others who approached them looking for seed. The growers appearing in these lists were often members although there are a number of names each year that are not found on the official membership roll. However, the crop varieties listed all came from the experiment station and since the dissemination of these improved varieties went through the WAEA, it is reasonable to assume that even if particular individuals on the lists were not members themselves at minimum they had obtained their initial stock of seed from one who was. Additional criteria for appearing on the list mostly dealt with meeting quality standards such as having grown the seed on land without weeds and having treated the seeds to prevent smut.

Unlike the Canadian organization, the WAEA focused on testing and distributing fewer varieties of each crop. The primary varieties were Swedish Select oats, Oderbrucker barley, and Silver King corn. Each of these followed a similar pattern from acquisition by the station to eventual widespread dissemination within the state. The Wisconsin Experiment Station had obtained Swedish Select in 1899 and had worked to improve it until 1902 when it was first distributed to the WAEA for cooperative experiments. By 1906 the testing phase had been completed and members had grown the variety only for seed. In 1911 the WAEA resumed experimentation on oats with an improved variety called Wisconsin Select. The Wisconsin Experiment Station had obtained Oderbrucker in 1898 from the Ontario Agricultural College; by 1905 the variety was improved and sent to the WAEA for trials.

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In 1908 the variety was officially released for dissemination. R.A. Moore first began testing Silver King corn in 1903 and released it for cooperative experiments in 1904. This information is collected in Table 4 below:

Table 3.4: Approximate Timeline of Important WAEA Crop Varieties

Variety:	Swedish Select (oats)	Oderbrucker (barley)	Silver King (corn)
Year obtained:	1899	1898	1903
Year released to WAEA:	1902	1905	1904
Year disseminated:	1906	1908	1907

3.4 Data and Empirical Strategy

3.4.1 Data

The primary data for the experiment association in Ontario are obtained from three sources. From the Annual Report of the Bureau of Industries for the Province of Ontario I obtain county and district level, crop, livestock, and market data for years 1882-1902. From the Annual Report of the Ontario Agricultural College and Experimental Farm, which often contained the Annual Report of the Agricultural and Experimental Union, I have obtained names and counties of each successful experimenter. I observe those experimenting with oats, corn, and wheat from 1891-1899, with barley from 1892-1899, and with peas from 1893-1899. Prior to 1891 there was some experimentation on crop varieties but few experimenters were involved and the listings reveal nothing about specific crops. I am unable to observe membership of the OAEU with the exception of one year, 1893. Climate data has been accessed through the National Climate Data and Information Archive. From this source I observe monthly average temperature and monthly rainfall at several weather stations within Ontario.

The primary data for the WAEA come from three sources. From the Annual Report of the Wisconsin State Board of Agriculture I obtain county level crop and livestock statistics for the years 1903-1912. A typical report from year t includes

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acreage for year t and bushels harvested in year $t-1$. It appears from the language used that the listed acreages do in fact refer to acres planted and yields do not include crop for silo.[4] From the annual reports of the Wisconsin Agricultural Experiment Association I obtain membership lists from 1903-1912 and lists of the growers of seed from 1904-1911 which allow me to observe names and counties.[5] The bulletins were published over the winter and in order to be included in the list of growers one must have seed available for the upcoming season. After 1912 the WAEA published its list of purebred seed growers separately from the annual report apparently since it had become lengthy and also since a separate publication could be released within a better timeframe relative to the planting season.[6] I obtain monthly weather data from the U.S. Historic Climatology Network for the year 1900-1915. With these records I am able to observe monthly temperatures (minimum, maximum, and average) and precipitation collected at weather stations in the region. Through the use of a triangular interpolation method it is possible to obtain county level observations. This is discussed in further detail later in this section.

3.4.2 Empirical Strategy

Both the OAEU and the WAEA were structured to encourage the diffusion of information and improved seed with the goal of both allowing researchers to determine the best varieties and to help farmers make wise planting decisions. I conduct an empirical analysis of each organization and estimate the extent of their success in facilitating the diffusion of biological and non-biological innovations originating from the experiment stations. If the OAEU and WAEA were successful I expect

[4]Further anecdotal evidence for belief that the acreage data includes crop for silage while my yield data is missing crop removed for silo is that the these agricultural statistics later appeared in biennial reports beginning around 1916, some of which disaggregate acreage into harvest for market and for silo with total acreages comparable to those reported 1903-1912.

[5]For the years 1904-1906 cities were included instead of counties and so counties were determined from city data.

[6]These have been obtained sporadically for years extending into the 1920's but with large gaps.

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to see counties with a higher concentration of experimenters to have higher yield rates, ceteris paribus. With the model for the OAEU I am primarily able to study the flow of information regarding the performance of crop varieties because what I observe are experimenting members each of whom may or may not have been also distributing seed. With the model for the WAEA I am able to investigate the flow of both information and improved seed. I observe seed growers affiliated with the association and therefore look for their influence on seed diffusion. I also separately observe members of the WAEA and this can capture their educational and information transmission function.

The models I estimate for these experiment associations each makes use of a separate panel dataset consisting of all counties and districts in the respective state or province. In order to analyze the impact of their activities I am interested in the effect of the measure of experimenters, seed growers, and members on the crop yield per acre in a county for each of the crops in my dataset that the associations worked with. For Ontario this is oats, peas, corn, barley, and wheat while for Wisconsin this is oats, corn, and barley.

For both regressions the central identifying assumption is that changes in experiment association activity within a county are unrelated to changes in unobserved determinants of crop productivity. In order to estimate the effect of the OAEU, I model yield per acre for a specific crop in county t and in year i under the following linear assumption,

$$y_{i,t} = \alpha_0 + \alpha_1 exper_{i,t} + \alpha_2 exper_{i,t-1} + \alpha_3 exper_{i,t-2} + \gamma W_{i,t} + C_i + T_t + \varepsilon_{i,t} \quad (3.1)$$

In equation (1) the dependent variable $y_{i,t}$ represents bushels per acre harvested in a county for a specific crop and is directly observed from the Ontario crop data while α_0, α_1, α_2, α_3, and γ are unknown parameters to be estimated. The OAEU experimenter count in the county is represented by $exper_{i,t}$. Given that experiments were conducted in period t with results and seed available in $t+1$, it is appropriate for this variable to be lagged in the regression. However, in order to account for the possibility that the effect is distributed over a period of time I include two lags,

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$exper_{i,t-1}$ and $exper_{i,t-2}$. I denote the vector of weather controls by W. County and year fixed effects are represented by C_i and T_t, respectively. Lastly, ε is a vector of unobserved variables that effect the bushels per acre harvested.

With the Ontario data I am also able to estimate two additional equations. These are created by using two alternative dependent variables, value per acre and the log of acres under a particular crop. The former is a measure that incorporates both yield per acre and the market price. For this regression I have insufficient data for corn and spring wheat, but am able to report results for the other crops. The latter is a measure of the acreage share of all farmland devoted to a particular crop. For this regression I have insufficient data for corn, but am able to report results for all other crops. Finally, in both of these regressions I also include a vector of controls for the capital levels within a county. This vector includes the value of farm implements, the value of farm buildings, and the value of livestock within the county. All other aspects of both regressions match equation (1).

In order to estimate the effect of the WAEA, I model yield per acre for a specific crop in county t and in year i under the following linear assumption,

$$y_{i,t} = \beta_0 + \beta_1 mem_{i,t} + \beta_2 grow_{i,t} + \beta_3 grow_{i,t-1} + \delta W_{i,t} + C_i + T_t + \varepsilon_{i,t}. \qquad (3.2)$$

In equation (2) the dependent variable $y_{i,t}$ represents bushels per acre harvested in a county for a specific crop. This is not directly observed from the Wisconsin crop data and therefore is calculated from the yield and acreage data that is present. The coefficients β_0, β_1, β_2, β_3, and δ are parameters to be estimated. The WAEA membership count in the county is represented by $mem_{i,t}$ and the number of WAEA seed growers in the county is represented by $grow_{i,t}$. The timing of the program is such that the growers I observe in year t are to have seed ready for distribution and planting in year t. However, I include the lag, $grow_{i,t-1}$, in the regression because it is reasonable to expect the effect to occur over more than one year. I include a vector of weather controls, W, and represent county and year fixed effects with C_t and T_t, respectively. Lastly, ε is a vector of unobserved variables that effect the bushels per acre harvested.

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3.4.3 Identification

In equation (1) the parameters I am interested in identifying are α_1, α_2, and α_3 which serve to capture the effects and lagged effects of experimentation. If the OAEU was successful in determining through experimentation the best varieties for a particular locality and in spreading this knowledge, I expect areas with higher numbers of experimenters to have higher yielding crops, ceteris paribus. Therefore, I expect to see $\alpha_2 > 0$, and if the effect is distributed over time, I expect $\alpha_3 > 0$ where α_2 and α_3 are the coefficients on $exper_{i,t-1}$ and $exper_{i,t-2}$ respectively. There is no strong reason to expect to measure a contemporaneous effect, but if one were present then I should see $\alpha_1 > 0$ where α_1 is the coefficient on $exper_{i,t}$.

In equation (2) the parameters I am interested in identifying are β_1, β_2, and β_3, which correspond to the effects of members, growers, and lagged growers respectively.[7] The WAEA attempted to disseminate seed as well as to educate farmers through formal workshops, published reports, and word of mouth. If the WAEA was successful in diffusing knowledge and improved seed, I expect areas with higher numbers of members and growers to have higher yielding crops, ceteris paribus. Since I observe WAEA seed growers with seed for sale that season it is reasonable to expect a contemporaneous effect, however, the lagged measure has been included in case this effect is distributed over time. This is reasonable because with more growers from the prior year, there is more seed available for sale to other farmers in which case I expect to see yields expand. Therefore, I expect to see $\beta_1 > 0$ and $\beta_2 > 0$ from the coefficients on mem and $grow_{i,t}$ respectively. If the effect of the seed dissemination efforts occurs over a longer time period I expect also to see $\beta_3 > 0$ from the coefficient on $grow_{i,t-1}$. Potential buyers from the WAEA seed growers were often non-WAEA members and therefore β_2 and β_3 measure the effect of this program.

[7] As mentioned earlier there is a great deal of overlap between lists of WAEA members and seed growers, however, neither list is a proper subset of the other. If any of those listed on the grower list were not actual members of the WAEA, I can at least be confident that they obtained their original stock of seed from one who was.

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Time-variant data allows me to plausibly consistently estimate equations (1) and (2) after controlling for county fixed effects. Time invariant county fixed effects control for aspects such as soil type, access to irrigation, and distance to the Ontario Agricultural College and Experimental Farm or to the Wisconsin Agricultural Experiment Station and its branches. Therefore the identification of the effect from the OAEU and WAEA comes through within county variation over time. I cluster the standard errors on the county. Also, year fixed effects control for all influences that are constant across counties in each time period. I control for weather shocks through the use of monthly climate variables. In order to control for temperature and precipitation in Wisconsin I use data from the U.S. Historic Climate Network for the years 1900-1915. In order to control for temperature and precipitation in Ontario I use data from the National Climate Data & Information Archive for the years 1886-1902. This climate data were collected at weather stations throughout the state or province and during the period studied often a county lacked a station. Therefore, to create county-year weather controls I use a method of triangular interpolation as in Kitchens (2012).[8] For each year, the latitude and longitude of each weather station is used to determine the three closest weather stations to each county seat and for each county the weather station data are weighted by this distance. Specifically, the weight for each measure is $w_i = \frac{1}{2}(1 - \frac{d_i}{d_1+d_2+d_3})$.

There are several sources of endogeneity that may enter regression equations (1) and (2). One potential source has to do with the selection of farmers into the association as experimenters. If it were true that on average the experimenters who joined were better farmers to begin with and therefore also had better crops it certainly could lead to my results overstating the effectiveness of the experiment associations. On the other hand it could be that experimenters joined in larger numbers when they sensed their crops were in trouble hoping to have access to better technology and to catch the attention of researchers. If this were the case and farmers tended to join when they had a negative forecast, thereby increasing the census of

[8] I appreciate the generosity of Carl Kitchens for access to the code and U.S. Historic Climate Data.

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experimenters within a county, any effect I find should be a lower bound. Another potential source of endogeneity arises if those experimenting had systematically underreported negative findings or had been excluded for other reasons for instance as per the policies of the OAEU. To the extent that one believes that the unsuccessful reports still resulted in information gains for farmers or researchers this would also probably introduce downward bias and cause the effect I estimate to be lower than in actuality. County and year fixed effects should control for many issues however this non-classical measurement error could introduce bias in a detrimental way if correlated with dependent variables. Endogeneity may also enter if it was the case that experimenters used their best land for the trials, but this seems unlikely especially in Ontario where directions specifically discouraged this practice. However, if farmers selected their best land anyway then it could be the case that the presence of experimenters was less valuable because the yield advantages in their reported results would be overstated. Finally, there could be cross county spillovers; counties with few experimenters may still benefit if there are experiments conducted near the county line. In this case my results should be a lower bound on the true effect. In many cases the potential sources of endogeneity should go in a direction causing downward bias. Nevertheless, as mentioned, it is also possible that endogeneity could present more of a problem.

3.5 Results

My main findings are that both the OAEU and WAEA had a statistically significant effect on the crop productivity of their respective regions, that the timing of this effect provides evidence for rapid diffusion through these networks, and that the greatest effect tended to be present in the crops that figured more prominently in their program of cooperative experimentation. When the OAEU had an effect on crop productivity it was delayed and often distributed over the two years beyond an experimental trial. On the other hand, the effect from the WAEA was immediate and it was necessary not only to have members present in a county, but also to have

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seed growers making the improved varieties available. These findings suggest that not only did the OAEU and WAEA have an effect on crop productivity, but that they accomplished their goal of swift diffusion. From the results it is possible to conclude that either the programs worked or there is an endogenous selection issue that is getting picked up and reflected in the findings. Based on the anecdotal evidence in the annual reports it seems the former is the case. Full results are collected in the appendix. For crop productivity one specification was used for all crops of the OAEU and these are reported in Table 8. I also report results for regressions in which the value per acre and the log of acres devoted to a particular crop appear as dependent variables. These are reported in Tables 10 & 11 respectively. For the WAEA results are reported for all three crops both with and without dropping Dane county. These are reported in Table 9. All regressions use both county and year fixed effects as well as monthly climate variables which control for weather shocks.[9]

Column (1) in Table 8 displays results demonstrating the statistically significant effect of OAEU experimenters on oats productivity. The coefficient of the lagged experimenter count within a county is 0.216 and a one standard deviation increase in oats experimenters in year $t-1$ is associated with a 0.075 standard deviation increase in oats bushels per acre in year t. The coefficient on $exper_{i,t-2}$ is 0.223 and a one standard deviation increase in oats experimenters in year $t-2$ is associated with a 0.077 standard deviation increase in oats bushels per acre in year t.[10] Both effects are statistically significant at the 5% level and the distributed lag provides evidence that the impact was not fully realized over a single time period. I also find a positive and statistically significant effect on the value per acre of oats and peas. This is reported in columns (13) and (14) found in Table 10.

Complementary to my empirical results is anecdotal evidence suggesting the OAEU perceived its own effectiveness. Some annual reports included favorable testimonials of farmers who had experimented with the crop. One such comment

[9]The tables report robust standard errors in parentheses clustered on the county and $^{*}p < 0.10$, $^{**}p < 0.05$, $^{***}p < 0.01$

[10]The elasticities are 0.009 for both lagged variables on oats.

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attested to the fact that the writer had been successful in promoting the usage of the variety in his community.[11] Further, in a typical annual bulletin following the numerical summary of experimental results, they would provide a small section with conclusions that typically listed which varieties had performed the best or were most popular. For oats during my sample period the preferred type was often the Siberian variety which, according to Zavitz (1903), became widely grown in the province. Interestingly I find a positive and significant effect of the OAEU on the share of farmland devoted to oats. This is reported in column (17) found in Table 11. This suggests that farmers began planting larger areas of oats in response to the experimentation efforts of the OAEU.

My findings also show a statistically significant effect of the OAEU on the productivity of Ontario's peas crop as shown in column (3) of Table 8. The coefficient of $exper_{i,t-1}$ is 0.238 and a one-standard-deviation increase in the number of experimenters is associated with a 0.089 standard deviation increase in yields per acre the following year.[12] There are mixed results pertaining to the effectiveness of the OAEU with other crops. The effect of experimentation on barley was also shown to be statistically significant, however, the results show that for this crop there was an immediate effect. This is illustrated in Table 8 in column (4). It seems odd that the data would allow observation of any immediate effect of the OAEU on crop productivities and it is possible that these results are reflecting omitted variable bias. Another possible explanation is that the results are picking up the coordination efforts of farmers in the province to settle on a higher yielding variety of barley independent of the activities of the OAEU. As I explain below in the context of Wisconsin, this would make sense in Ontario if farmers were responding to the desires of the brewing industry for a particular, uniform crop. However, I find no effect of the OAEU on the value of barley per acre. This is reported is column (15)

[11] In the 1899 OAEU Annual Report, Nelson Montieth of Perth County recounts his experience, "By an experiment with oats, I introduced an early variety into our section, which has been of material advantage to the farmers, and is now generally grown by them."

[12] The elasticity is 0.01 for peas

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found in Table 10.

In an earlier version of the paper I reported results in which a positive and statistically significant contemporaneous effect was observed for winter wheat as well. Winter wheat was planted in the fall and harvested the following summer. I have since found anecdotal evidence strongly indicating inconsistencies with how the Ontario Bureau of Industries and the OAEU assigned crop years in the data I have collected. This had the consequence of assigning year t to a winter wheat experimenter count that really should be assigned year $t-1$. After accounting for this issue I find no effect of the OAEU on the productivity of winter wheat. There was no statistically significant effect demonstrated by the results for corn or spring wheat. That this would be the case is not surprising; much of the activity of the OAEU with corn was with growing crop for fodder and spring wheat was of relatively low prominence for both Ontario and the association.

The results from the WAEA are reported in Table 9 with and without Dane County which is home to Madison and the University of Wisconsin. As indicated in the bottom row of the table Dane has been dropped from the estimation reported in even numbered columns. The reason for doing this is that many of the members in Dane County were likely more closely associated with the Experiment Station or agricultural college than typical for the WAEA and therefore not likely to be quite the same as ordinary members or growers in terms of disseminating seed to ordinary farmers. Further, for Dane County there may be reason to question the assumption that ordinary farmers always obtained their WAEA grown seed through the experiment association. It is possible that some farmers in Dane County received seed directly from the Experiment Station though this was certainly not the case elsewhere in the state. The findings displayed in column 7 of Table 9 show that the coefficient on $grow_{i,t}$ is 0.327 and statistically significant at the 5% level.[13] A one standard deviation increase in the number of oats growers was associated with a 0.084 standard deviation increase in the yield of oats. The success of the Swedish Select oats was recognized by members of the WAEA and documented in their

[13]The elasticity is 0.02 for oats.

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annual reports. Each year a few members would submit a letter explaining their experience with the variety. In one such letter Edward F. Heuer of Waushara county explains that his crop yielded about 40 bushels per acre while that of his neighbor yielded 26 bushels per acre. He points out that assuming a market price of $0.35 per bushel and 20 acres devoted to oats, the net advantage associated with this improved variety would be $98. (WAEA 1904).

Also of note is the statistically significant positive effect on barley which reflects the efforts of WAEA seed growers to disseminate barley. The coefficient on barley growers is 0.111 which is statistically significant at the 10% level.[14] Their efforts were concentrated primarily on promoting a variety called Oderbrucker which was known to be higher in a type of protein that may have made them better for feeding than the existing variety, Manshury. However, it was unclear at least initially whether this new variety would be good for brewing. In reporting on the experiments in 1904, R.A. Moore mentioned that the Oderbrucker variety would not be released until a laboratory in Chicago had completed a malting test and he expressed his concern that entire communities would successfully coordinate on the same variety to suit the market , were strongly influenced by the brewing industry (WAEA 1904). This variety was later demonstrated to be acceptable both for brewing and for feed. Brewers desired a uniformity across the barley crop and so it was advantageous to work to resolve a coordination problem. This being the case, it is possible my empirical results are reflecting best responding behavior in light of farmers' purposes for growing the crop and the actions of the others in their county. The extent to which this coordination was led by the WAEA is not entirely clear. More research is warranted to shed light on the question of whether farmers were responding to the information provided by the experiment associations or to the influence of the brewing industry. At the end of the day it is probably true that both forces played some role.

Finally, the coefficient on corn is -0.381 which is significant at the 5% level when Dane County, which lies in prime Wisconsin corn country, is removed from the

[14]The elasticity for barley is 0.033

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estimation. Returning Dane County does not change the sign, but the effect loses statistical significance. While my empirical results show a negative and statistically significant effect of the WAEA's work on the productivity of corn there is also anecdotal evidence at least to support the absence of a significant, positive effect. In the WAEA Annual Bulletin of 1905, R.A. Moore had indicated his expectation that Silver King corn would follow the same trajectory as Swedish Select oats. Shortly thereafter a number of members had submitted favorable reviews of their experience with this variety. However, in the 1910 Annual Bulletin, Moore describes their present position with their work on corn and barley as "at the threshold of success" (WAEA 1910). Indeed this would be an odd way to describe the progress of the past five years had he believed that the results had fulfilled the initial optimism. On the other hand, Moore was not ready to declare success with barley either, contrary to my findings. It is possible that some of the difficulty with these crops had to do with the failure to find appropriate varieties for particular regions. After all, the WAEA worked with comparatively few varieties of each crop and it may be the case that oats with its Swedish Select variety was simply much more appropriate for universal adoption of a single variety than corn.

Besides simply having found a statistically significant effect for both the OAEU and WAEA something more can be said about the time period over which the diffusion occurred. The distributed lag demonstrates that the influence of the OAEU on crop productivity was delayed and spread over time. Given the structure of the program the finding of a delay in its impact is reasonable. In year t, varieties were provided to experimenters to plant small test plots and in the year $t+1$ researchers learned the results of the tests and experimenters had seed to plant and sell. Further, given the sort of information to be spread it is reasonable that a delay in the rise of productivity is natural. In addition to the time needed to complete experiments and scale up production of seed, it likely took some time for farmers and seed suppliers to adjust their behavior. Similarly, for the WAEA, that the results show an immediate impact is reasonable given the fact that my measure of growers is of members that had seed available for distribution that same year.

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There is no statistically significant lagged effect of grower count which runs against what one might have expected. While there is an effect on productivity due to the dissemination activities of seed growers, my findings demonstrate no effect from the WAEA members who were not growing seed for distribution that year. Therefore, in order for there to be an effect from the WAEA the county needed to have members that were also seed growers. However, when seed growers were present the effect was immediate. So while the timing of the effect differed for each association, the findings concerning both experiment associations are intuitive as explained by the preceding.

Finally, the results show that the effects tended to show up in the crops on which the respective association had most focused. For both the OAEU and WAEA the effect on oats was positive and statistically significant and in both cases this was among the very first crops tested by the association. In the OAEU there generally were more experimenters working with oats than any other crop. The exception was winter wheat, which received the greatest focus beginning in 1895. Behind oats in experimenter count was peas, the other OAEU crop for which there was a statistically significant positive, delayed effect. The story is similar in Wisconsin. In the WAEA by 1906 the number of growers of barley and corn had exceeded that of oats. However, Swedish Select had been their first success and continued to be mentioned frequently in the annual reports despite it no longer being necessary to determine the effectiveness of the variety through experimentation. It is then reasonable that they would shift their resources largely into corn and barley in the hopes of making progress there as well. Taken altogether, the effectiveness of these two organizations tended to be associated with crops that were prominent in their experimentation programs.

3.6 Concluding Discussion

Rarely have economic historians been able to trace the information flow that leads to the diffusion of technology. In this paper I am able to use two concrete examples

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to contribute to our knowledge regarding the diffusion of technology. I study the Ontario Agricultural and Experimental Union (OAEU) and the Wisconsin Agricultural Experiment Association (WAEA) during the early years of their existence, 1886-1900 and 1903-1911, respectively. In each case I find evidence that the networks were effective. I find that both organizations had a positive and statistically significant effect on the productivity of oats and barley as measured by average yield per acre within a county. I also find a positive and statistically significant effect of the experimentation activities of the OAEU on the productivity of peas.

My results also provide insight into how the timing of the diffusion patterns through each mechanism worked. I find a delayed effect of the cooperative experiment activities of the OAEU and an immediate effect of the dissemination activities of the WAEA. These results provide insight into the rate of diffusion through the network, which in both cases, was quite rapid. As mentioned earlier one aspect that may have encouraged swift diffusion might be the fact that these were publicly funded entities wanting to pass along the innovations without regard for retaining property rights. The improved seeds that the associations dealt with were very different from the hybrid corn that would follow a few decades later. Importantly these seeds were not sterile. Once a stock of seed was obtained farmers were both able to plant their fields in subsequent years and were able to sell seeds to others.

Finally it is noteworthy that the effects of the OAEU and WAEA tended to be present in crops for which experimental activity was relatively intense during the period I study. The results match the historical evidence for how these associations were structured and behaved. Among both associations a major focus was with oats both in terms of the number of members working with the crop and in terms of the frequency of its mention in the annual reports. In Ontario the wheat crop was also a major focus and I do find an effect there as well.

An additional consideration that deserves more research is the influence that industry may have had on the behavior of these associations. It was certainly the case that each association controlled the seed developed at their respective experiment stations. However, it is possible that this research was influenced by strong outside

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interests. Notably in Wisconsin there is at least some evidence that the association was responding to the wishes of the brewing industry with respect to their treatment of the barley crop. This may have been true in Ontario as well. Future work is warranted into other types of networks as well. An interesting set of examples from the same time period are the Dairymen's Associations which were present in most dairy producing areas. It is also insightful to consider how the properties that made these farmer associations so amenable to swift diffusion might be replicated elsewhere.

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Table 3.5: Summary Statistics: OAEU Experimenters

	Oats					Corn					Peas				
Year	Mean	St Dev	Min	Max	N	Mean	St Dev	Min	Max	N	Mean	St Dev	Min	Max	N
1890	0.00	0.00	0	0	46	0.00	0.00	0	0	46	0.00	0.00	0	0	46
1891	0.78	1.11	0	4	46	0.22	0.59	0	3	46	0.00	0.00	0	0	46
1892	2.65	2.81	0	12	46	0.43	0.78	0	4	46	0.00	0.00	0	0	46
1893	2.15	2.22	0	11	46	0.72	0.83	0	3	46	1.52	1.96	0	8	46
1894	2.59	2.35	0	9	46	0.43	0.58	0	2	46	1.35	1.58	0	6	46
1895	1.83	1.76	0	6	47	0.60	0.74	0	2	47	1.49	1.98	0	10	47
1896	1.85	2.11	0	8	46	1.06	1.17	0	4	47	1.53	1.87	0	7	47
1897	1.89	2.24	0	9	46	0.83	1.03	0	4	47	1.19	1.45	0	6	47
1898	2.24	2.57	0	12	46	0.94	1.33	0	5	47	1.47	1.91	0	7	47
1899	2.47	2.45	0	11	47	0.26	0.57	0	2	47	1.91	2.13	0	8	47
1900	.	.	.	.	0	.	.	.	.	0	.	.	.	.	0
	Barley					W.Wheat					S.Wheat				
Year	Mean	St Dev	Min	Max	N	Mean	St Dev	Min	Max	N	Mean	St Dev	Min	Max	N
1890	0.00	0.00	0	0	46	0.00	0.00	0	0	46	0.00	0.00	0	0	46
1891	0.00	0.00	0	0	46	0.00	0.00	0	0	46	0.78	1.11	0	4	46
1892	0.11	0.31	0	1	46	1.26	1.87	0	7	46	0.78	1.05	0	4	46
1893	0.24	0.52	0	2	46	1.28	1.94	0	7	46	0.61	0.98	0	4	46
1894	0.61	1.02	0	4	46	1.70	2.43	0	8	46	0.41	0.88	0	5	46
1895	0.47	0.86	0	4	47	2.13	2.60	0	10	47	0.26	0.49	0	2	47
1896	0.55	0.88	0	4	47	1.98	2.46	0	10	47	0.36	0.70	0	3	47
1897	0.36	0.92	0	5	47	4.96	6.51	0	26	47	0.66	0.96	0	4	47
1898	0.66	1.03	0	4	47	4.02	4.46	0	20	47	1.32	1.29	0	5	47
1899	1.11	1.20	0	4	47	1.47	2.06	0	10	47	0.62	0.97	0	4	47
1900	.	.	.	.	0	.	.	.	.	0	.	.	.	.	0

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Table 3.6: Summary Statistics: Ontario Crop Yields

	Oats					Corn					Peas				
Year	Mean	St Dev	Min	Max	N	Mean	St Dev	Min	Max	N	Mean	St Dev	Min	Max	N
1886	35.59	3.85	30	44	45	.	.	.	.	.	21.93	2.19	17	27	45
1887	28.99	5.13	20	41	45	48.51	13.11	27	92	45	16.58	4.64	10	31	45
1888	34.65	7.94	20	47	45	64.39	18.38	28	95	45	20.28	5.05	10	28	45
1889	32.70	4.41	25	41	45	52.67	10.15	35	81	45	18.34	3.69	9	27	45
1890	27.00	3.49	18	36	46	56.54	10.50	37	75	46	19.37	2.90	12	25	46
1891	39.08	5.25	26	49	46	69.36	13.33	40	89	46	23.51	3.19	14	29	46
1892	33.61	4.56	25	41	46	60.34	9.57	40	90	46	17.42	4.13	7	27	46
1893	28.88	4.36	19	38	46	56.49	10.58	38	76	46	18.26	3.08	13	28	46
1894	28.24	4.69	17	38	46	56.46	9.35	30	79	46	17.07	2.82	11	22	46
1895	34.44	5.07	26	46	46	68.44	13.59	40	95	46	19.23	3.21	14	28	46
1896	33.39	3.77	25	41	47	62.66	13.72	38	88	47	20.35	2.76	15	26	47
1897	33.63	4.41	22	42	47	64.01	13.26	36	83	47	15.96	2.86	10	24	47
1898	35.06	4.58	23	45	47	54.74	13.96	30	89	47	15.81	3.26	9	24	47
1899	36.31	4.67	27	47	47	.	.	.	.	0	19.25	2.98	12	25	47
1900	36.37	4.41	28	45	47	.	.	.	.	0	19.80	2.85	14	25	47
	Barley					W.Wheat					S.Wheat				
Year	Mean	St Dev	Min	Max	N	Mean	St Dev	Min	Max	N	Mean	St Dev	Min	Max	N
1886	26.33	3.07	20	34	45	20.14	2.95	15	26	45	15.76	2.52	12	22	45
1887	22.41	3.20	17	30	45	16.45	2.40	11	26	45	11.50	3.09	6	21	45
1888	26.74	5.75	16	35	45	17.86	4.28	8	28	44	16.92	3.13	12	24	45
1889	25.78	3.15	20	32	45	16.60	2.76	12	24	44	14.03	2.34	10	20	45
1890	21.96	3.19	16	30	46	17.94	3.27	12	24	46	13.36	2.27	9	18	46
1891	28.25	3.93	16	40	46	23.12	4.15	16	30	44	20.11	3.21	14	30	46
1892	23.81	3.08	17	32	46	21.40	2.77	15	27	44	12.85	2.78	8	19	46
1893	20.77	2.97	14	26	46	18.78	2.40	12	23	46	11.82	2.35	6	18	46
1894	21.56	3.40	14	28	46	20.01	2.95	12	25	46	14.03	2.52	9	21	45
1895	24.91	3.82	18	33	46	20.03	3.95	10	28	46	15.38	2.82	8	21	46
1896	26.12	3.23	18	33	47	18.24	4.58	7	27	47	13.21	2.88	8	20	47
1897	25.31	3.00	18	30	47	21.25	5.48	10	30	47	14.93	2.05	10	20	46
1898	27.41	3.70	16	33	47	23.62	2.91	18	30	47	16.81	2.59	11	23	47
1899	28.39	3.53	22	35	47	14.84	3.80	8	27	47	16.20	2.60	11	21	47
1900	28.06	3.23	21	34	47	20.86	3.29	12	26	47	17.42	2.23	12	22	47

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Table 3.7: Summary Statistics: Wisconsin

	Wisconsin Crop Yields														
	Oats					Corn					Barley				
Year	Mean	St Dev	Min	Max	N	Mean	St Dev	Min	Max	N	Mean	St Dev	Min	Max	N
1903	27.31	8.53	8	61	69	21.64	14.36	0	101	69	23.31	11.33	2	84	69
1904	29.00	8.18	8	61	66	18.09	10.02	0	39	66	27.59	16.92	1	136	66
1905	31.10	10.58	10	72	66	29.94	22.44	1	188	66	26.05	10.36	0	61	66
1906	29.34	8.25	4	57	66	32.71	13.98	2	101	66	26.74	12.86	1	91	66
1907	19.82	5.46	9	41	70	20.97	8.40	1	53	70	20.35	12.58	2	103	70
1908	25.23	7.32	7	46	70	23.31	17.41	1	141	70	26.24	15.79	5	141	70
1909	28.17	7.24	10	47	68	24.09	9.80	0	46	68	22.78	5.91	3	50	68
1910	19.81	8.66	5	42	69	23.34	12.39	2	70	69	16.79	8.99	2	50	69
1911	23.41	7.00	2	35	70	25.54	7.86	4	42	70	18.92	5.37	1	35	70
1912	29.73	8.89	4	54	71	23.65	21.29	1	184	71	20.40	7.11	8	45	71
	WAEA Seed Growers														
	Oats					Corn					Barley				
Year	Mean	St Dev	Min	Max	N	Mean	St Dev	Min	Max	N	Mean	St Dev	Min	Max	N
1903	0.00	0.00	0	0	69	0.00	0.00	0	0	66	0.00	0.00	0	0	66
1904	0.85	0.95	0	5	66	0.00	0.00	0	0	66	0.00	0.00	0	0	66
1905	1.08	1.23	0	7	66	0.38	0.67	0	3	66	0.00	0.00	0	0	66
1906	1.45	1.66	0	8	66	2.24	2.71	0	16	66	3.70	4.78	0	29	66
1907	2.53	3.03	0	17	70	8.14	9.93	0	63	70	5.74	6.54	0	40	70
1908	2.56	2.59	0	12	70	5.67	7.47	0	42	70	4.97	5.71	0	31	70
1909	2.97	3.03	0	13	68	13.31	16.17	0	100	68	12.97	16.97	0	123	68
1910	3.41	3.57	0	16	69	12.91	15.55	0	92	69	25.57	31.43	0	211	69
1911	0.47	0.91	0	5	70	17.27	20.19	0	125	70	15.70	19.52	0	127	70
1912	.	.	.	.	0	.	.	.	.	0	.	.	.	.	0

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Table 3.8: OAEU Regression Results 1886-1900; dependent variable is yield per acre

Crop	Oats	Corn	Peas	Barley	W. Wheat	S. Wheat
	(1)	(2)	(3)	(4)	(5)	(6)
Experimenters_t	0.159	-0.727	0.116	0.420**	0.043	0.022
	(0.097)	(0.699)	(0.103)	(0.175)	(0.078)	(0.109)
$\text{Experimenters}_{t-1}$	0.216**	0.766	0.238**	0.366	0.123	0.065
	(0.105)	(0.642)	(0.110)	(0.222)	(0.087)	(0.129)
$\text{Experimenters}_{t-2}$	0.223**	1.091	-0.165	0.088	-0.134	0.143
	(0.103)	(0.901)	(0.123)	(0.189)	(0.088)	(0.188)
County	Yes	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes	Yes
Weather	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.619	0.388	0.527	0.598	0.436	0.632
N	409	363	409	409	359	408

Table 3.9: WAEA Regression Results 1903-1911; dependent variable is yield per acre

Crop	Oats	Oats	Corn	Corn	Barley	Barley
	(7)	(8)	(9)	(10)	(11)	(12)
Members	0.012	-0.005	0.047	0.091	-0.004	0.004
	(0.033)	(0.054)	0.101	(0.118)	(0.062)	(0.098)
Growers_t	0.327**	0.403**	-0.221	-0.381**	0.111*	0.177*
	(0.159)	(0.175)	(0.153)	(0.189)	(0.062)	(0.099)
Growers_{t-1}	0.021	0.117	0.307	0.413	-0.088	-0.133
	(0.184)	(0.188)	(0.226)	(0.317)	(0.042)	(0.061)
County	Yes	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes	Yes
Weather	Yes	Yes	Yes	Yes	Yes	Yes
R^2	0.370	0.369	0.212	0.226	0.167	0.167
N	529	521	529	521	529	521
Dane County	Yes	No	Yes	No	Yes	No

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Table 3.10: OAEU Regression Results 1886-1900; dependent variable is value per acre

Crop	Oats	Peas	Barley	W. Wheat
	(13)	(14)	(15)	(16)
Experimenters_t	0.049	0.041	0.082	0.035
	(0.032)	(0.058)	(0.136)	(0.061)
$\text{Experimenters}_{t-1}$	0.060*	0.115*	0.037	0.071
	(0.031)	(0.060)	(0.172)	(0.071)
$\text{Experimenters}_{t-2}$	0.056	-0.061	-0.012	-0.125*
	(0.034)	(0.068)	(0.110)	(0.068)
Implements Value	0.194	0.878	-0.825	-0.601
	(0.405)	(0.589)	(1.712)	(1.920)
Building Value	-0.318*	-0.470**	0.025	0.659
	(0.174)	(0.192)	(0.559)	(0.538)
Livestock Value	0.458**	0.39	0.532	-0.158
	(0.151)	(0.243)	(0.546)	(0.620)
County	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes
Weather	Yes	Yes	Yes	Yes
R^2	0.864	0.751	0.398	0.648
N	408	408	408	358

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Table 3.11: OAEU Regression Results 1886-1900; dependent variable is the log of acres under the particular crop

Crop	Oats	Peas	Barley	W. Wheat	S. Wheat
	(17)	(18)	(19)	(20)	(21)
Experimenters_t	0.001	0.002	0.017	0.007	-0.005
	(0.003)	(0.007)	(0.011)	(0.006)	(0.030)
$\text{Experimenters}_{t-1}$	0.005*	0.008	0.024	0.017	-0.039
	(0.003)	(0.007)	(0.021)	(0.009)	(0.025)
$\text{Experimenters}_{t-2}$	0.005	0.007	0.002	-0.0003	-0.015
	(0.003)	(0.006)	(0.021)	(0.009)	(0.023)
Implements Value	-0.104**	-0.460**	0.329**	-0.550	-0.689**
	(0.039)	(0.143)	(0.110)	(0.357)	(0.265)
Building Value	-0.007	-0.074	-0.029	0.108	-0.089
	(0.012)	(0.052)	(0.051)	(0.087)	(0.055)
Livestock Value	-0.020	-0.007	0.167***	-0.156**	-0.030
	(0.020)	(0.049)	(0.041)	(0.072)	(0.085)
County	Yes	Yes	Yes	Yes	Yes
Year	Yes	Yes	Yes	Yes	Yes
Weather	Yes	Yes	Yes	Yes	Yes
R^2	0.613	0.327	0.604	0.162	0.586
N	362	362	362	358	361

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