Brinkmanship on the Commons: A Laboratory Experiment Related to African Pulaar Herders

Steven C. Wilhelms
Dept. of Agricultural Economics
Mississippi State University
P.O. Box 5187, 329 Lloyd-Ricks-Watson Bldg.
Mississippi State, MS 39762
662-312-6799
Scw46@msstate.edu

Kalyn T. Coatney
Dept. of Agricultural Economics
Mississippi State University
P.O. Box 5187, 365 Lloyd-Ricks-Watson Bldg.
Mississippi State, MS 39762
662-325-7983
k.coatney@msstate.edu

Anita M. Chaudhry
Economics Department
California State University, Chico
400 West First Street, Butte Hall 649B
Chico, CA 95929
530-898-5494
achaudhry@csuchico.edu

Aaron D. Rodgers
Mississippi Dept. of Agriculture and Commerce
121 North Jefferson Street
Jackson, MS 39201
601-359-1110
aaron@mdac.ms.gov

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1.0 Introduction

Beginning in the late 20th century, international remittances have become a growing source of additional income for families in developing countries. Remittance is the money earned by international migrants which is sent back to their native countries to help support their families. As of 2010, the flow of remittances exceeded \$440 billion world-wide where \$325 billion were transferred to developing countries, and in several instances accounted for more than 10% of the nation's gross domestic product (Nyamongo et al., 2012).

The remittances literature has focused primarily on the impacts on the financial sector, as well as individuals living near or in poverty. Githaiga (2014) concluded that remittances have an adverse effect on the development of the financial sector, primarily because most transfers of remittances were informal, through unofficial channels, altruistic, and used for household consumption. Nyamongo et al. (2012) identify that remittances could facilitate entrepreneurship contributing to economic growth and financial development, if governments promote the usage of formal channels when transferring remittances.

In many developing countries, the financial sector is underdeveloped, especially in rural areas. The World Bank (2011) reported that over 50% of the collective remittances to the Sub-Saharan region in Africa use informal channels to transfer the remittances, due to lower transaction costs and accessibility to funds. Therefore, families receiving remittances must find opportunities outside the financial sector in which to invest.

Since the introduction of international remittances, Senegalese herders (for example) have invested in consumption and converting from subsistence herding to commercial production to improve welfare and financial stability. The building of larger herds of cattle places additional stress on the delicate Sub-Saharan resources, which are largely common pool resources. The largely decentralized government delegates the regulation and assessment of productive usage of pastureland to local rural councils. This has in turn increased conflict between those who share the common pool resource.

Sustainable management of common pool resources has long been a topic of debate and analysis beginning with Hardin (1968). Hardin predicted that without central government intervention the production decisions of self-interested producers (cattle producers for example) would lead to economically inefficient outcomes and exploitation of the natural resources leading to what has been coined as the “Tragedy of the Commons”. Since then, a plethora of research has been conducted to test this tragic prediction and find adequate mechanisms to mitigate the probability of its occurrence. The most notable research was conducted by Noble Laureaute Elinor Ostrom (1999). Among other important findings, Ostrom and others, have found that cooperation is more likely to occur at the local level resulting in more economically efficient outcomes and successful management practices, thus mitigating the need for centralized government regulation. From extensive research across a multitude of environmental, cultural and institutional settings, Ostrom has argued that there is no singular regulatory mechanism that can be universally employed to efficiently manage common pool resources. This implies a more regionally and behavioral based approach is needed to adequately address the strategic challenges that may (or may not) facilitate the efficient use of commons resources.

The motivation for the current analysis originated from the experiences and observations of Aaron Rodgers with the Pulaar people. Traditional Pulaar herders have long inhabited commons property areas in and around the Sub-Saharan regions in Senegal, Africa. They have lived a fairly nomadic life conducive to raising livestock based on the ever changing availability of pastureland in the vast semi-arid savannahs. However, in recent years the Pulaar people have taken to a more village based lifestyle, herding cattle from a central base of operations. The use of the commons is delegated by the central government to local village councils, not all of which are comprised of the same tribe. Rodgers observed significant heterogeneity in the degree of pastureland degradation across villages.

This analysis identifies the short run strategic implications of remittances invested in commercial production using a village based grazing system. The goal of this research is to take a step back from long run analyses and gain better understanding of the short run strategic dynamics that these types of herders face. In doing so, animal growth dynamics is a key feature of the modeling framework. Growth can be accounted for as either a long run population dynamic, shorter run individual live weight growth, or some combination of both. Admittedly, a short run analysis limits the scope of understanding long run resource sustainability as has long been the approach in the literature (e.g. Hardin, 1968; Ostrom et al., 1992; Ostrom et al., 2006; Higgins et al., 2007; Hussan and Tschirhart, 2013). However, a deeper understanding of short run incentives will provide a stronger foundation for extensions into a richer long run framework.

Treating remittances as exogenous, a conceptual one-shot dynamic game is developed which facilitates an analysis of the resulting competitive implications of a village based commercialized grazing system. Structural identification of animal growth and production cost dynamics results in an interesting game of brinksmanship leading up to a war-of-attrition. The game is then structurally identified in a laboratory experiment, where by the underlying mixed strategy predictions of the conceptual game are tested. Two new human behavioral attributes are controlled for in the experiment which may negatively impact cooperative behavior, thus reducing economic efficiency. Psychological tests were conducted to determine an individual's predisposition for assertive and aggressive behavior. For example, when two assertive players meet who feel they have a right to the resource, or when two aggressive type players meet, the likelihood the players will coordinate is reduced.

Like outcomes observed by Ostrom across the globe, and Rodgers of Pulaar villages, the results demonstrate significantly heterogeneous outcomes ranging from economically efficient coordination to inefficient outcomes that would be associated with heavier exploitation of the resource. The source of the variability in outcomes is largely due to the mixed strategies associated with brinksmanship and war-of-attrition, in addition to human behavior. For instance, more risk averse individuals are less likely to maintain a challenge for the resources and exit the game (sell livestock) earlier, thus reducing resource stress. Also, coordination, where one rival exits early, is significantly undermined by assertive and aggressive individuals, thus increasing the demand on resources.

2.0 Literature Review

At the turn of the 21st century, research within this field had been extended to include using game theory to help analyze efficient yet sustainable common pool resource practices. Florian Diekert (2012) reviewed recent game-theoretic research in the field of collective action problems surrounding common pool resources, but the research reviewed had reoccurring themes of cooperation and coordination. None of the research used a sequential game revolving around producer decisions which incorporates mixed strategy and multiple sub-game Nash equilibria that could produce similar results without cooperation and coordination.

Keser and Gardner (1999) conducted game-theoretic common pool resource experiments that questioned if individuals chose the Nash equilibrium in common pool resource games in repeated volunteer dilemma game, and their results showed that subjects rarely played a Nash equilibrium, no significant attempts at achieving cooperation, and the major concern was avoidance of negative rents applied if no one volunteered. Their research, like most published common pool resource management games, is looking at the effects of using volunteering, cooperative theory, and/or coordination on the resource and not analyzing the purely competitive production decisions which could be influenced by psychological traits and levels of risk aversion between rivals that could yield Nash equilibria for sustainable management practices of the common pool resource.

3.0 Conceptual Herder Model and Game Structure

The following are the basic elements for the development of the one-shot dynamic game analyzed in this study. Let $i = [1, 2]$ herders be symmetrically endowed and exogenously invest x_{it} remittance dollars at $t = 0$, where $t \in (0, T]$ and T is the longest possible time spent grazing during the production period. The cattle are subsequently grazed in a commons property and sold in their entirety at any time $t \in (0, T]$.

3.1 Animal Growth and Production Costs

The first structural consideration for the game is that of animal growth. Because the focus of this analysis is on the short run impacts of remittance dollars, animal growth is modeled in terms of pounds (value) of production. There are numerous nonlinear dynamic animal growth functions from which to choose, some of which have been shown to be more appropriate for modeling the life-cycle of various breeds and sexes of cattle (e.g. Brown et al., 1976; Goonewardene et al., 1981; Lopez et al., 2000; and Froni et al., 2009).[1] For these life cycle models to be of practical use, the producer must know the age of animals (Maples et al., 2015). However, it is often the

[1] Classic sigmoidal growth functions, such as the Gompertz, Verhulst Logistic and Richards, have been shown to appropriate when modeling the growth of an animal from birth to maturity.

case that buyers in the United States do not know the age of the animal, and would most likely be the case in Africa as well. The growth function for this analysis, i) does not rely on the knowledge of the animal(s) age, ii) has been found to be a good approximation for cattle growth for as long as a year, and is reasonably tractable for economic modeling (Maples et al., 2015). In any case, the dynamic nonlinear functional form chosen will not impact the main aspects of the game structure. Assuming the herders purchase symmetric type(s) of animal(s), the functional form of growth given unbounded resources for each herder is

$$f_i(t) = M - e^{-kt}\left(M - m\right), \tag{1}$$

where m is the pounds of live animal purchased, M is the seasonal capacity of total production from the available forage in the commons and $M > m$.[2] The parameter $k > 0$ is the instantaneous growth rate parameter in relation to reaching M from m, and t is the time parameter.

By inspection, the growth equation (1) is strictly concave. Therefore, the herder will experience diminishing returns in regards to time spent grazing the animal(s). The reason is that over the time, an increasing portion of the daily forage consumed goes to maintaining the animals current body size at the expense of growth as it approaches its limiting factor M in equation (1). A detailed explanation of these consumption and growth relationships can be found in standard animal nutrient requirements manuals (NRC, 2000).

No livestock production literature, however, could be found to guide the development of a fairly representative functional form for the dynamic costs of grazing cattle. Upon further

[2] The first order differential equation is $f'(t) = k\left(M - f(t)\right)$, subject to $f(0) = m$. Note, the capacity parameter M may vary over regions and grazing seasons. Modeling extension could allow capacity to be a function of previous stocking rates, and/or the stochastic processes of rainfall, and may be constantly at equilibrium or non-equilibrium states (Cowling, 2000; Lambin et al., 2001; Vetter, 2005; Higgins et al., 2007; Derry and Boone, 2010).

discussion below, the functional form chosen has merit. Dynamic production costs are simply represented as

$$g_i(t) = cm\mathrm{e}^{rt}, \tag{2}$$

where the initial cost of the animal(s) is a onetime investment of m pounds at a price $c > 0$ per pound.[3] From the assumption that remittance dollars are fully invested, $x_{i0} = cm$. Finally, $r > 0$ is a general instantaneous growth rate of production cost, without explicitly accounting for input prices.

By inspection, the production cost equation (2) is strictly convex. This functional form is a general representation of the likely dynamics of production costs based on the production realities of a village based grazing system. In this type of production system, herders generally travel their cattle out from the village every day to graze. Cattle are then brought home each night to protect them from predators, thieves and harsh weather events (i.e. dust storms). In the early portion of the production period animals consume roughage relatively close to the village and are close to m in body size. During this time, the required animal energy costs expended in the search of forage is relatively low. As time elapses, however, the cattle grow in accordance to equation (1), and the animals must be taken increasingly farther from the village in search of available forage.[4] As cattle grow, the required energy costs to maintain body mass also increases nonlinearly. By extension, to maintain body growth above maintenance, the distance traveled and energy costs in search of roughage increases nonlinearly. Taken together, these production realities would most likely result in convex costs of production. The same reasoning could be applied to the cost of herder effort.

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[3] The first order differential equation is $g'(t) = rg(t)$, subject to $g(0) = cm$.

[4] This presumes that forage growth near the village is inadequate to sustain growing animals throughout the production period.

3.2 *Herder Market Timing Decision*

Given the underlying animal growth and cost equations, the herder's market timing (exit) decision is now presented. Because the model focuses on a single annual grazing season, discounting of profits is ignored. The payoffs of each herder are contingent on the number of herders competing for the available forage. The fewer herders' reduces both animal and herder search costs dedicated toward competition for the available forages. The competitive interdependences conditional on the number of herders can be captured in the following general way. The state contingent profit function for each herder is

$$\pi_i = p\left(M - \mathrm{e}^{-kt}\left(M - m\right)\right) - cm\mathrm{e}^{(r|n)t} - F\,, \tag{3}$$

where herders are assumed to sell in a competitive output market at price $p > 0$ and experience a fixed cost of marketing $F > 0$. In regards to production costs efficiency parameter $r \mid n$, where $(r \mid n = 1) < (r \mid n = 2)$.[5]

The resulting optimal exit from the commons (market timing) and equilibrium profit are

$$t^* = \frac{\log\left[\dfrac{kp(M-m)}{cm(r \mid n)}\right]}{k + (r \mid n)} \text{ and} \tag{4}$$

[5] Past literature has considered the impacts of competition on population growth and long run resource sustainability. Cournot and other types of competition between animal species and their resulting impact on the competition between plant species has been recognized in the economics and biological literature (Finoff and Tschirhart, 2007; Finnoff et al., 2008; Hussain and Tschirhart, 2010 and 2013), as well as dynamic stocking density rates, forage growth and forage composition (Cowling, 2000; Lambin et al., 2001; Vetter, 2005; Higgins et al., 2007; Derry and Boone, 2010).

$$\pi_i^* = p\left(M - \frac{(M-m)\left(\frac{k(M-m)p}{cm(r\mid n)}\right)^{-\frac{k}{k+r}}\left(k+(r\mid n)\right)}{(r\mid n)} \right) - F \quad ,[6] \tag{5}$$

where $\frac{\partial t^*}{\partial (r\mid n)} < 0$ and $\frac{\partial \pi_i^*}{\partial (r\mid n)} < 0$ for all restrictions on the parameters. Given $(r\mid n=1) < (r\mid n=2)$, it naturally follows that $(\pi_i^* \mid n=2) < (\pi_i^* \mid n=1)$. Therefore, profits are improved via reduced competition. Assuming $0 < (\pi_i^* \mid n=2)$ an internal solution exists if $t^* < T$.

Figure 1 provides a continuous time representation of the value of marginal product and marginal factor costs, assuming parameters k = 0.3, m = 250, M = 750, r = 0.0867 for two herders, and r = 0.0512 for one herder for $t \in (0,13]$. In reality however, herders make discrete choices of when to market the cattle (exit), given they take their animals out to graze and return home daily or perhaps even weekly owing to the nomadic abilities of the Pulaars. Assuming herders are restricted to make decisions in discrete periods, then $t \in [1,...,13]$. The arrow lines in the graph depict a potential inter period transition between marginal factors costs after one herder has market his cattle (exit). Figure 2 provides the continuous time representation of profits and transitions across profitability under the same corresponding assumptions as figure 1.

3.3 Herder Game

Table 1 depicts the payoffs to the sequential game played between two herders. The relative payoffs in each period of the game are derived using the corresponding transitions across profitability as depicted in figure 2 when one herder exits the game (markets cattle). A finite set of (thirteen) periods represents the production period. The game begins in period 0 with both

[6] The second order condition is satisfied for all positive restrictions on the parameters.

herders investing remittance dollars. It is not until period 1 that each herder can decide to sell the livestock (exit). In each period, the herders make a simultaneous decision to either sell all their livestock or wait. The row decisions in each period represent the own herder and the column decisions are the rival. If a herder sells, then that herder exits the game in that period. Therefore, it is not until period 2 that any given herder has the potential to be the sole remaining herder and have the opportunity of earning the higher payoffs as depicted in figure 2. Finally, in period 13 the game ends with both herders selling, if and only if, both herders are still in the game. The end period can either represent the full extraction of forage resources or simply the end of the marketing season.

If one or both herders sell, then they will earn the period payoffs associated with the 2 herder payoff scenario depicted in figure 2. If one herder sells while the other waits, the herder that waits would rationally stay in the game until the maximum of the remaining 1 herder payoff scenario depicted in figure 2 is reached. If both herders sell, then they have the option to earn the next 2 herder payoff with certainty in the next period. This payoff in the static can be thought of as the 'sure thing' payoff.

The static equilibrium strategy solutions are also provided in table 1 for each period including the pure strategy Nash equilibria (PSNE) and the corresponding mixed strategy Nash equilibria (MSNE) for selling. For periods 1 to 4, the PSNE is for both herders to wait. If both herders are still in the game in period 5, there are two PSNE and as such a MSNE. The same follows for periods 6 through 12.

A graphical representation of the respective period payoffs and mixed strategy sell (*q*) and wait (*r*) are provided in figure 3. As can be seen, the relative difference between selling first or at the same time and selling second is the smallest in period 5. Also depicted in figure 3 is the mixed strategy sell. As can be seen the changes in the mixed strategies is generally increasing, the lowest nonzero in period 5 and do not begin decreasing until after period 9. Lower/higher levels of mixed strategy sell result in a higher/lower probability that both herders will wait.

Figure 4 presents the expected payoffs and the relative period differences between the value of selling first or simultaneous and selling second from playing mixed strategies for each period. As can be seen the highest expected mixed strategy payoff is at period 5 and steadily decreases the longer the herders are both in the game. The expected mixed strategy payoff for both players is the inverse of the difference in value between selling first or simultaneous to waiting and selling second.

3.4 Properties of the Sequential Herders Game and Equilibrium Concepts

Given the there are two PSNE and one MSNE at periods 5 through 12, where the MSNE sell are non-constant makes the solution of a unique subgame perfect equilibrium via backward induction difficult if one exists at all. However, the game has several interesting properties and similarities to two well-known games [brinksmanship and war-of-attrition] from which draw inferences of the potential outcomes of the game.

To begin, the period mixed strategies creates a risky environment for the herders to continue to simultaneously wait in hopes of being the second seller who earns a greater payoff for any given period. The creation of risk by purposely waiting and staying in the game results in a Brinksmanship game similar in spirit to that of nuclear deterrence (Nalebuff, 1987) and the Escalating Game of Chicken game (Chuah et al., 2011). In the current context, if both herders wait and go over the 'brink' in period 5, the risk that the rival will not sell increases, hence making both herders worse off in expected returns. However, in period 9 the risk associated with mixed strategy sell decreases, thus the incentive to stay in the game decreases. Realizing the increasing risk and decreasing in expected mixed strategy returns incentivizes the herders to sell earlier.

However, the value of selling second is greater than selling first. Therefore, the herders are caught on the horns of weighing the likelihood their rival will sell at any point in the game against the higher payoff if their rival sells first. As such, the game the herders face also has many of the same properties of the war-of-attrition game (Bulow and Klemperer, 1997), where in the current context each rival 'waits out' the nerve of their rival to assume risk.

Finally, because the maximum payoff for selling first is less than that of selling second, cooperation requires one of the herders to exit first. Without a side payment mechanism results in the Volunteer's Dilemma that has been recognized in social dilemmas of provide public goods (Diekman, 1985; Archetti, 2009). The dilemma in the current context is deciding who is going to accept the lower of the two maximum payoffs at period 5 to avoid entering into the Brinksmanship portion of the game starting in period 5.

3.5 Expected Laboratory Experiment Outcomes

Given the risky properties of the game just discussed, it is conceivable that heterogeneous experimental subjects as to i) risk aversion, and ii) nerve will result in a distribution of outcomes. For instance:

1) Subjects will be prone to consider the risk established by the sequence of unique PSNE and changes in the MSNE.

2) It is highly unlikely that subjects will sell in the first four periods.

3) Those who are risk averse will likely sell earlier than their more risk loving rivals.

4) Those who are more aggressive or assertive subjects are more likely to have the 'nerve' it takes to wait longer.

These predictions provide testable hypotheses for the following experiment.

4.0 Experimental Design

The data analyzed in the research was collected through conducting multiple laboratory experiments consisting of voluntary undergraduate and graduate students from Environmental Economics & Management, Agribusiness, Forestry, and Agricultural Economics.

In order to reach a sufficient sample size, a total of 3 experimental sessions were administered to gather enough observations, and each experimental session consisted of 12 students resulting in 36 test subjects. Each session was comprised of 10 production rounds, where after completion of each round would be randomly matched with a different unknown competitor. A maximum time allotment of 13 time periods was established within each production round, where each paired producer would make simultaneous decisions at the beginning of each period whether to “sell” their output or to “hold” and stay in production.

Conclusion of each production round occurs when at least one of the paired subjects have sold their output. Every participant was given the same information, and table 2 depicts the payoffs for each time period throughout the production round along with a running total of their current earnings was calculated upon the completion of each production round. Each participant were informed of their rival’s production decision at the end of each period.

Human behavioral facts were collected at the completion of the experiment. Each experimental participant’s level of risk aversion was determined by their completion of Holt and Laury’s Risk Aversion Pre-test and the aggregate results are depicted in table 3. In addition to this test, each experimental participant was required to answer Rathus’s Assertiveness questionnaire and Buss and Perry’s Aggression Test.

Assertiveness implies a general "right to something" while aggressiveness measures how much a person may want to "hurt others" to achieve what that individual may want. Alberti and Emmons defines assertive behavior as, "Behavior which enables a person to act in his own best interests, to stand up for himself without undue anxiety, to express his honest feeling comfortably, or to exercise his own rights without denying the right of others." (1974) Appendix A shows the questionnaire that participants filled out to configure their level of assertiveness. The lower the combined score implies a higher level of assertiveness. Other published authors within the mental health field support Alberti and Emmons's definition.

Marsha Richins cited Arnold Buss's definition of aggressiveness which happens to be the most cited in research: "A response that delivers noxious stimuli to another organism." (74) The Buss-Perry Aggression Questionnaire analyzes an individual's aggression based on four separate subtraits: Physical Aggression, Verbal Aggression, Anger, and Hostility. Buss and Perry detail each subtrait of aggression by saying, "Physical and verbal aggression, which involves hurting or harming others, represent the instrumental or motor component of behavior. Anger, which involves physiological arousal and preparation for aggression, represents the emotional or affective component of behavior. Hostility, which consists of feeling of ill will and injustice, represents the cognitive component of behavior." (457) Appendix B reports the aggressiveness questionnaire and the higher the combined score of the test reflects a higher level of aggressiveness within that particular individual

5.0 Data and Econometric Modelling

[NEED DISCRIPTIVE STATISTICS TABLES AND DISCUSSION FOR AGGRESSION AND ASSERTIVE QUESTIONAIRE]

For many who conduct survival analysis prefer the utilization of the Cox model instead of a logistic model because the log model does not do a sufficient job recognizing survival times nor any censored data. The logistic model and Cox model have particular differences in what each model is trying to estimate. The logistic model focuses on the estimation of the ratio of odds or risk ratio while the Cox model focuses on the estimation of the hazard ratio. The semi-parametric Cox proportional hazard model was chosen because it best estimated the different variables and covariates used in the regression. The Cox model has some key assumptions that make this type a good choice in many different situations when running survival analysis like: the estimated hazards are always non-negative and the ability to estimate the betas which will allow for the derivation of the hazard ratio even without a specified baseline hazard. Survival analysis utilizes the maximum likelihood function in order to estimate the time to the event occurring.

5.1 Cox Proportional Hazard Model

The Cox proportional hazard model is a type of regression model that is semi-parametric. This method is widely used in survival analysis because of its ability to derive and explain the explanatory variables or covariates' effect on hazard rates. This method will make fewer assumptions than the parametric method while making more assumptions than the non-parametric method, but a stark difference is that parametric models will make assumptions about the distribution of the baseline hazard function. A main assumption of the Cox model is that the proportional hazard, the hazard for one individual is constant or fixed for all other individuals. The general formula for the Cox Proportional Hazard model can be written out as:

$$h(t,X) = h_0(t)\exp\left(\sum_{i=1}^{p}\beta_i X_i\right) \tag{6}$$

The final specification of the model for the regression is:

$$
\begin{aligned}
h(t,X) = h_0(t) * \exp(&\beta_1 rep2 + \beta_2 rep3 + \beta_3 SF + \beta_4 S\sec + \beta_5 dif + \beta_6 mixsell \\
&+ \beta_7 running\_total + \beta_8 propA + \beta_9 running\_total * propA \\
&+ \beta_{10} assertscore + \beta_{11} aggresScore)
\end{aligned} \tag{7}
$$

where our dependent variable, *h(t,X)*, represents the period in which each individual sells (exits). The notation, $h_0(t)$, represents our baseline hazard function which indicates the underlying hazard and if all covariates were equal to zero all that would be left is the baseline hazard function ($h_0(t)$).

5.2 Independent Variables

Every explanatory variable or covariate in the model specification was included because of the economic theory or to address replication and experimental design issues, strategic or economic behavioral aspects, and psychological behavioral aspects. Eleven different independent variables were included in the specification of the model in order to address certain types of issues that may affect the validity of the results.

When analyzing experimental data, replication issues will materialize if experiments were ran multiple times and consisting of heterogeneous participants. *Rep2* and *Rep3* variables represent the experiment replicated for the second time and third time with each having a random group of twelve heterogeneous volunteers. These two categorical variables were included in the specification in order to address replication issues between the different repetitions and each participant in the experiment. These should have no significance that would change the maximum likelihood estimates since they are essentially dummy variables.

SF (sell first) variable consisted of producers within the game of random pairings who chose to sell and exit the production cycle before their rival. This variable established which producer decided to sell their output at a certain period without knowledge of their rival's simultaneous decision. *Ssec* (sell second) variable needed to be controlled for because *SF* established who sold first which makes the *Ssec* conditional on which period their rival decided to sell. Within the game, if a paired individual decided to sell first in a certain period on their own accord, then the one-shot game was over for that pairing for that round because the second seller was forced to sell in the highest payoff remaining. Neither of these variables should have any significant effect on the maximum likelihood estimates, but could provide insights when running comparative statics on the average period sold for each variable.

The *dif* and *mixsell* variables were created and inserted into the model that looked at the strategic decision-making behavior. The calculation that was made for the *dif* variable was simply derived from subtracting the *SF* payoff in the current time period from the optimal *Ssec* payoff in the remaining time periods. Table 4, which was visible to each participant in each experiment, shows the payoffs for being the first seller in each of the respective time periods and the payoffs for being the second seller if their rival decided to sell. For example, if a competitor decided to sell in the fifth period, then their first seller payoff would be 152.8. Their rival who decided to wait, would then get the highest payoff remaining in the column after their rival has sold which in this example would be time period 7's payoff of 231. This turns out to be a 78.2 difference in the two payoffs. Figure 5 shows the frequency of the sellers in each of the potentially time periods and the *dif* curve shows where the smallest and biggest difference in the sell first and sell second payoffs occur within the game. The lowest difference between the separate payoffs occurs at period 5 which is where the highest hazard rate resides. A high hazard rate implies a greater probability of a producer choosing to sell. This significant time period introduces the beginning of the Brinksmanship. Figure 5 also explicitly shows that each time period after five will yield an increased difference in the separate payoffs which decreases the hazard rate; these time periods mark the start of the "slippery slope" which indicates an increasing probability of both rivals holding until the end where they are both forced to sell. Intuitively, the *dif* variable would yield a negative significant effect on the regression which would affect the hazard rate considering the fact that it is based on financial payoff discrepancies from each time period which affects the hazard rate and an individual's strategic behavior. The *mixsell* variable tracks an individual's incentive to sell based on strategic decision-making behavior of when their rival will choose to sell. The assumption which makes this variable powerful is that it takes into perspective an individual believing that his rival is playing a mix strategy myopically (not looking into the potential future payoffs, but only current guaranteed period payoffs) beginning in the fifth period, and this increases the probability of waiting for their rival to eventually choose sell. That belief in their competitor's strategy applies only to the current time period. As each time period pass without a seller, tremendous pressure mounts toward selling now for the myopic player as guaranteed payoffs decrease in every successive period. If this occurs, then that individual's rival should look to the future payoffs after their competitor has sold and decide to wait. By controlling for risk aversion, the *mixsell* results stem from a risk neutral individual. The *mixsell* variable should result in a significant negative relationship to the hazard rate.

Several behavioral aspects, resulting from economic influence, were controlled for to see if in fact these particular economic behaviors had a significant impact on the hazard rate over time. *Running Total* represent the payoffs accumulated and adjusted from each production cycle (round) to give an up-to-date status of revenue earned; this variable represents the "wealth effect" that may affect a rival's decision-making behavior. Every competitor could see their own accumulated payoffs from each round. An individual's beginning wealth may have some negative relationship with the hazard rate when running the regression based on the intuition that the more wealth an individual has the higher the likelihood of that individual incurring more risk for a potentially higher future payoff. But if their rival does not sell first, then the negative payout have a smaller impact on their wealth than an individual with less wealth.

Risk aversion of an individual, denoted as the *PropA* variable, is a behavioral characteristic that affects economic decision-making which the regression model shows has a positive coefficient in the parameter estimate. Table 3 depicts the choices an individual has in order to configure their level of risk aversion. This simply states that as every time period passes, risk is increased which causes the hazard rate to increase, and clearly shows that the more risk adverse an individual is implies a higher probability of selling. *PropA* variable controlled for every risk averse individual which left just risk neutral players, and was essential for the *mixsell* results to come from risk neutral players. The more risk averse an individual is, the more likely there is a stronger positive relationship with the fluctuating hazard rate when playing mixed strategy. An interacting term was formulated from the *running total* and *PropA* that was used in our regression. This interacting term looks at the ending wealth or potential wealth at the end of current period. This interacting term is derived from the beginning wealth accumulated from past periods and the associated gamble (risk accrued from uncertainty of a potential future payoff). Risk averse individuals may not want to absorb the associated gamble for a chance at a higher payoff, but coupling that notion with a high level of wealth may change the level of risk an individual may be willing to take on. From the data collected in the experiments, the more wealth an individual has should result in a decreasing relative risk aversion while lower wealth will cause an individual a higher relative risk aversion moving forward.

Based on the attributes for each of the psychological inference, a prediction of a higher level of aggressiveness and assertiveness will have a negative relationship with the hazard ratio.

This makes intuitive sense if an individual feels like they have a right to higher payoffs or would take smaller profits just to incur the same fate to their rival.

6.0 Empirical Results

The Maximum Likelihood Estimates of the Cox model are provided in table 5. Table 5 also reports that both the likelihood ratio and the Wald (sandwich) test provide an overall test that the model specified as a whole can predict positive and negative changes in the hazard rate and the percentage of the observations that were censored because a rival pairing did not choose to sell their output in the 12^{th} period which resulted in that pairing forced to sell in the last period (13^{th} period). The sample size was small which shows different values, but with at least one of the tests, the likelihood ratio is most preferred, shows that there will be at least one regression coefficient that is significantly different than zero. Table 5 visibly shows parameter coefficients, standard error, tests for significance, and the hazard ratio (the exponentiated coefficient). Note that there may not be an intercept because in Cox model regression, the intercept is absorbed into the baseline hazard function which was stated earlier is unspecified.

The parameter estimates for the dummy variables, *Rep2* and *Rep3*, was negative for the second replication and positive for the third replication. Neither of the estimates nor the sign of these estimates were significantly different from zero so we fail to reject the null hypothesis. The inclusion of the *SF* and *Ssec* variables also had small coefficients that were showed a positive relationship with the hazard rate, but they resulted in not being significantly different from zero which implies that we fail to reject the null hypothesis. The *dif* variable showed a negative relationship with the hazard rate, a chi-square value of 17.2147, and test of significance shows that it is highly significant where we reject the null hypothesis.

The *mixsell* variable was the main driver of the model because of the 133.153 chi-square value and shows high significance which implies that we reject the null hypothesis. The *mixsell* has a negative relationship with the hazard rate which can be interpreted as the hazard rate increases (probability to sell) then the mixed strategy is to wait for the rival to sell. The *running total* and *assertscore* both had high significance at a level of .005 which implies that we reject the null hypothesis in a 95% confidence interval and the *PropA, running_total*PropA*, and *aggrescore* were all significant at a level of 0.1 which states that in a 90% confidence interval we will reject the null hypothesis. The *running_total*PropA*, and *aggrescore* both showed a negative relationship with the hazard ratio which implies that individuals that are aggressive and/or are willing to "gamble" based on the initial wealth accumulated would increase their probability to wait to sell in hopes of a higher payoff in the end of the game.

7.0 Conclusion

Introducing an additional source of remittance investment enables nomadic tribes to engage in village based commercial agriculture. Increased herd size and semi-sedentary grazing alters the competitive interactions between once nomadic herders, either within or across villages. However, it is not necessarily the case that economically inefficient and potential resource degradation will be observed, even in the short run.

Experimental results show significantly heterogeneous outcomes ranging from economically efficient outcomes to increasingly heavier exploitation of the resource. Individual beliefs about rivals' actions, the wealth effect, behavioral and psychological attributes all significantly drive the heterogeneity of these outcomes. These results are consistent with those observed from long run analyses based on games that require cooperation and coordination between users of a commons resource to achieve economic efficiency and sustainable resources.

In all, the potential for economically inefficient outcomes and increased resource stress may be indirectly related to insufficient financial institutions to invest remittance dollars, and directly related to villager beliefs about their rights to the resource (assertive human behavior), and animosity between rival villagers and/or neighboring villages (aggressive human behavior). Therefore, the establishment of a trusted central banking system, with adequate infrastructure to serve rural communities, may incentivize beneficiaries of the remittance dollars an alternative source of money management and investment. Additionally, centralized regulatory bodies may benefit from mediating strategic and human conflict between villages and herders through assisted arbitration in lieu of enforcing universal land use regulations.

Appendix A: Sample Instructions and Questionnaire I: Rathus Assertiveness Test (Rathus 1973)

For each item, please circle the answer choice that is most accurate for you. Use the following answer choices:

3 = very much like me
2 = rather like me
1 = slightly like me
-1 = slightly unlike me
-2 = rather unlike me
-3 = very much unlike me

3 2 1 -1 -2 -3	(1) Most people seem to be more aggressive and assertive than I am.
3 2 1 -1 -2 -3	(2) I have hesitated to make or accept dates because of "shyness."
3 2 1 -1 -2 -3	(3) When the food served at a restaurant is not done to my satisfaction, I complain about it to the waiter or waitress.
3 2 1 -1 -2 -3	(4) I am careful to avoid hurting other people's feelings, even when I feel that I have been injured.
3 2 1 -1 -2 -3	(5) If a salesperson has gone to considerable trouble to show me merchandise that is not quite suitable, I have a difficult time saying "No."
3 2 1 -1 -2 -3	(6) When I am asked to do something, I insist upon knowing why.
3 2 1 -1 -2 -3	(7) There are times when I look for a good, vigorous argument.
3 2 1 -1 -2 -3	(8) I strive to get ahead as well as most people in my position.
3 2 1 -1 -2 -3	(9) To be honest, people often take advantage of me.
3 2 1 -1 -2 -3	(10) I enjoy starting conversations with new acquaintances and strangers.
3 2 1 -1 -2 -3	(11) I often don't know what to say to people I find attractive.
3 2 1 -1 -2 -3	(12) I will hesitate to make phone calls to business establishments and institutions.
3 2 1 -1 -2 -3	(13) I would rather apply for a job of for admission to a college by writing letters than by going through with personal interviews.
3 2 1 -1 -2 -3	(14) I find it embarrassing to return merchandise.
3 2 1 -1 -2 -3	(15) If a close and respected relative were annoying me, I would smother my feelings rather than express my annoyance.
3 2 1 -1 -2 -3	(16) I have avoided asking questions for fear of sounding stupid.
3 2 1 -1 -2 -3	(17) During an argument, I am sometimes afraid that I will get so upset that I will shake all over.
3 2 1 -1 -2 -3	(18) If a famed and respected lecturer makes a comment which I think is incorrect, I will have the audience hear my point of view as well.

3 2 1 -1 -2 -3	(19) I avoid arguing over prices with clerks and salespeople.
3 2 1 -1 -2 -3	(20) When I have done something important or worthwhile, I manage to let others know about it.
3 2 1 -1 -2 -3	(21) I am open and frank about my feelings.
3 2 1 -1 -2 -3	(22) If someone has been spreading false and bad stories about me, I see him or her as soon as possible and "have a talk" about it.
3 2 1 -1 -2 -3	(23) I often have a hard time saying "No."
3 2 1 -1 -2 -3	(24) I tend to bottle up my emotions rather than make a scene.
3 2 1 -1 -2 -3	(25) I complain about poor service in a restaurant and elsewhere.
3 2 1 -1 -2 -3	(26) When I am given a compliment, I sometimes just don't know what to say.
3 2 1 -1 -2 -3	(27) If a couple near me in a theater or a lecture were conversing rather loudly, I would ask them to be quiet or take their conversation elsewhere.
3 2 1 -1 -2 -3	(28) Anyone attempting to push ahead of me in line is in for a good battle.
3 2 1 -1 -2 -3	(29) I am quick to express an opinion.
3 2 1 -1 -2 -3	(30) There are times when I just can't say anything.

Appendix B: Sample Instructions and Questionnaire I: Aggression Test (Buss and Perry 1992)

For each item, please circle the answer choice that is most accurate for you. Use the following answer choices:

1=not like me at all

2=mostly not like me

3= somewhat like me

4=mostly like me

5=very like me

1 2 3 4 5	(1) Once in a while I can't control the urge to strike another person.
1 2 3 4 5	(2) I sometimes feel like a powder keg ready to explode.
1 2 3 4 5	(3) If somebody hits me, I hit back.
1 2 3 4 5	(4) Sometimes I fly off the handle for no good reason.
1 2 3 4 5	(5) If I have to resort to violence to protect my rights, I will.
1 2 3 4 5	(6) My friends say that I'm somewhat argumentative.
1 2 3 4 5	(7) At times I feel I have gotten a raw deal out of life.
1 2 3 4 5	(8) I am sometimes eaten up with jealousy.
1 2 3 4 5	(9) Other people always seem to get the breaks.
1 2 3 4 5	(10) I tell my friends openly when I disagree with them.
1 2 3 4 5	(11) I flare up (i.e., get angry) quickly but get over it quickly.
1 2 3 4 5	(12) When people annoy me, I may tell them what I think of them.
1 2 3 4 5	(13) I am suspicious of overly friendly strangers.
1 2 3 4 5	(14) There are people who pushed me so far that we came to blows.
1 2 3 4 5	(15) I often find myself disagreeing with people.
1 2 3 4 5	(16) When frustrated, I let my irritation show.
1 2 3 4 5	(17) Given enough provocation, I may hit another person.
1 2 3 4 5	(18) I sometimes feel that people are laughing at me behind my back.
1 2 3 4 5	(19) Some of my friends think I'm a hothead.
1 2 3 4 5	(20) I get into fights a little more than the average person.
1 2 3 4 5	(21) I have trouble controlling my temper.
1 2 3 4 5	(22) I have threatened people I know.
1 2 3 4 5	(23) I can think of no good reason for ever hitting another person.
1 2 3 4 5	(24) I have become so mad that I have broken things.
1 2 3 4 5	(25) I wonder why sometimes I feel so bitter about things.
1 2 3 4 5	(26) I know that "friends" talk about me behind my back.

1 2 3 4 5	(27) I can't help getting into arguments when people disagree with me.
1 2 3 4 5	(28) I am an even-tempered person.
1 2 3 4 5	(29) When people are especially nice, I wonder what they want.

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Table 1. Sequential Herder Game

period		sell (r)	wait (1-r)	PSNE 1	PSNE 2	MSNE {r, q}
1	**sell (q)**	6.9, 6.9	6.9, 231.0	{Wait, Wait}		0
	wait (1-q)	231.0, 6.9	78.3, 78.3			
2	**sell (q)**	78.3, 78.3	78.3, 231.0	{Wait, Wait}		0
	wait (1-q)	231.0, 78.3	122.5, 122.5			
3	**sell (q)**	122.5, 122.5	122.5, 231.0	{wait, wait}		0
	wait (1-q)	231.0, 122.5	145.8, 145.8			
4	**sell (q)**	145.8, 145.8	145.8, 231.0	{wait, wait}		0
	wait (1-q)	231.0, 145.8	152.8, 152.8			
5	**sell (q)**	152.8, 152.8	152.8, 231.0	{wait, sell}	{sell, wait}	0.0709
	wait (1-q)	231.0, 152.8	146.8, 146.8			
6	**sell (q)**	146.8, 146.8	146.8, 231.0	{wait, sell}	{sell, wait}	0.1651
	wait (1-q)	231.0, 146.8	130.1, 130.1			
7	**sell (q)**	130.1, 130.1	130.1, 228.1	{wait, sell}	{sell, wait}	0.2096
	wait (1-q)	228.1, 130.1	104.1, 104.1			
8	**sell (q)**	104.4, 104.4	104.4, 220.1	{wait, sell}	{sell, wait}	0.2247
	wait (1-q)	220.1, 104.4	70.9, 70.9			
9	**sell (q)**	70.9, 70.9	70.9, 208.0	{wait, sell}	{sell, wait}	0.2288
	wait (1-q)	208.0, 70.9	30.2, 30.2			
10	**sell (q)**	30.2, 30.2	30.2, 192.5	{wait, sell}	{sell, wait}	0.2263
	wait (1-q)	192.5, 30.2	-17.3, -17.3			
11	**sell (q)**	-17.3, -17.3	-17.3, 174.2	{wait, sell}	{sell, wait}	0.2198
	wait (1-q)	174.2, -17.3	-71.2, -71.2			
12	**sell (q)**	-71.2, -71.2	-71.2, 153.5	{wait, sell}	{sell, wait}	0.2122
	wait (1-q)	153.5, -71.2	-131.8, -131.8			
13	**sell**	-131.8, -131.8	x, x	{sell, sell}		
		x, x	x, x			

Table 2. Payoff Table Visible to Each Subject During Experiment Sessions

period	Your payoff each period if you sell first, or in the same period as rival	Rival's payoff each period if he/she sells first, or in the same period as you	Your payoff each period ***after*** your rival has sold first	Rival's payoff each period ***after*** you have sold first
0	0.0	0.0	0.0	0.0
1	6.9	6.9	16.5	16.5
2	78.3	78.3	98.6	98.6
3	122.5	122.5	155.2	155.2
4	145.8	145.8	192.6	192.6
5	152.8	152.8	215.5	215.5
6	146.8	146.8	227.4	227.4
7	130.1	130.1	231.0	231.0
8	104.4	104.4	228.1	228.1
9	70.9	70.9	220.1	220.1
10	30.2	30.2	208.0	208.0
11	-17.3	-17.3	192.5	192.5
12	-71.2	-71.2	174.2	174.2
13	-131.8	-131.8	153.5	153.5

Note: Whenever one of the paired rivals sold their output (exited the game), their rival was forced to sell their output in the highest payoff period remaining for the second seller.

Table 3. Holt and Laury Risk Aversion Pre-test and Results

	Ten Paired Lottery-Choice Decisions				
Lottery	Option A	Option B	Expected Payoff Difference by Choosing Option A over B	Choose Option B	Percent of Subject Pool Choosing Option A to B
1	1/10 of $5.00, 9/10 of$4.00	1/10 of $10.00, 9/10 of$0.25	2.875	insane	100.00
2	2/10 of $5.00, 8/10 of $4.00	2/10 of $10.00, 8/10 of $0.25	2.000	highly risk loving	100.00
3	3/10 of $5.00, 7/10 of $4.00	3/10 of $10.00, 7/10 of $0.25	1.125	very risk loving	94.44
4	4/10 of $5.00, 6/10 of $4.00	4/10 of $10.00, 6/10 of $0.25	0.025	slightly risk loving	86.11
5	5/10 of $5.00, 5/10 of $4.00	5/10 of $10.00, 5/10 of $0.25	-0.625	risk neutral	58.33
6	6/10 of $5.00, 4/10 of $4.00	6/10 of $10.00, 4/10 of $0.25	-1.500	slightly risk averse	47.22
7	7/10 of $5.00, 3/10 of $4.00	7/10 of $10.00, 3/10 of $0.25	-2.375	very risk averse	19.44
8	8/10 of $5.00, 2/10 of $4.00	8/10 of $10.00, 2/10 of $0.25	-3.250	highly risk averse	5.55
9	9/10 of $5.00, 1/10 of $4.00	9/10 of $10.00, 1/10 of $0.25	-4.125	extremely risk averse	0.00
10	10/10 of $5.00, 0/10 of $4.00	10/10 of $10.00, 0/10 of $0.25	-5.000	comatose	0.00

Table 4. Analysis of Maximum Likelihood Estimates of Cox Proportional Hazard Model with Sandwich Variance Estimates ±

Variable	Parameter Estimates (std. error)	Standard Error Ratio	Chi-Square	Pr > Chi-Square	Hazard Ratio
Intercept	n/a	n/a	n/a	n/a	n/a
Experimental Session 2	-0.08931 (0.1354)	0.916	0.4346	0.5097	0.915
Experimental Session 3	0.00517 (0.1270)	0.880	0.0017	0.9675	1.005
First Seller	0.08152 (0.1087)	0.429	0.5625	0.4533	1.085
Second Seller	0.01105 (0.1053)	0.411	0.0110	0.9165	1.011
Probability to Wait	-0.00374 *** (0.0009)	0.576	17.2147	< .0001	0.996
Incentive to Sell	-3.14950 *** (0.2729)	0.398	133.1526	< .0001	0.043
Accumulated Wealth	-0.00121 *** (0.0004)	0.826	8.5738	0.0034	
Risk Aversion	0.89367 * (0.5113)	0.684	3.0546	0.0805	
Wealth accounting for risk	-0.00086 * (0.0005)	0.604	2.9549	0.0856	
Assertiveness Level	-0.00597 *** (0.0020)	0.778	8.7369	0.0031	0.994
Aggressiveness Level	-0.00478 ** (0.0024)	0.711	4.0641	0.0438	0.995
Likelihood Ratio ***			104.1906	< .0001	
Score (Model-Based) ***			82.2684	< .0001	
Score (Sandwich) ***			33.0277	0.0005	
Wald (Model-Based) ***			73.0900	< .0001	
Wald (Sandwich) ***			382.7019	< .0001	
Total Number of Obs.	349				
Number of Obs. Censored	25[1]				
Percentage of Obs. Censored	7.16				

±Significantly different from zero at significance level at α = .01(***), at α = .05(**), and at α = .10(*)

[1]Rival pairing did not sell output by 12th period; was then forced to sell in 13th period.

Figure 1. Profit Maximization Problem and Transition When One Herder Exits

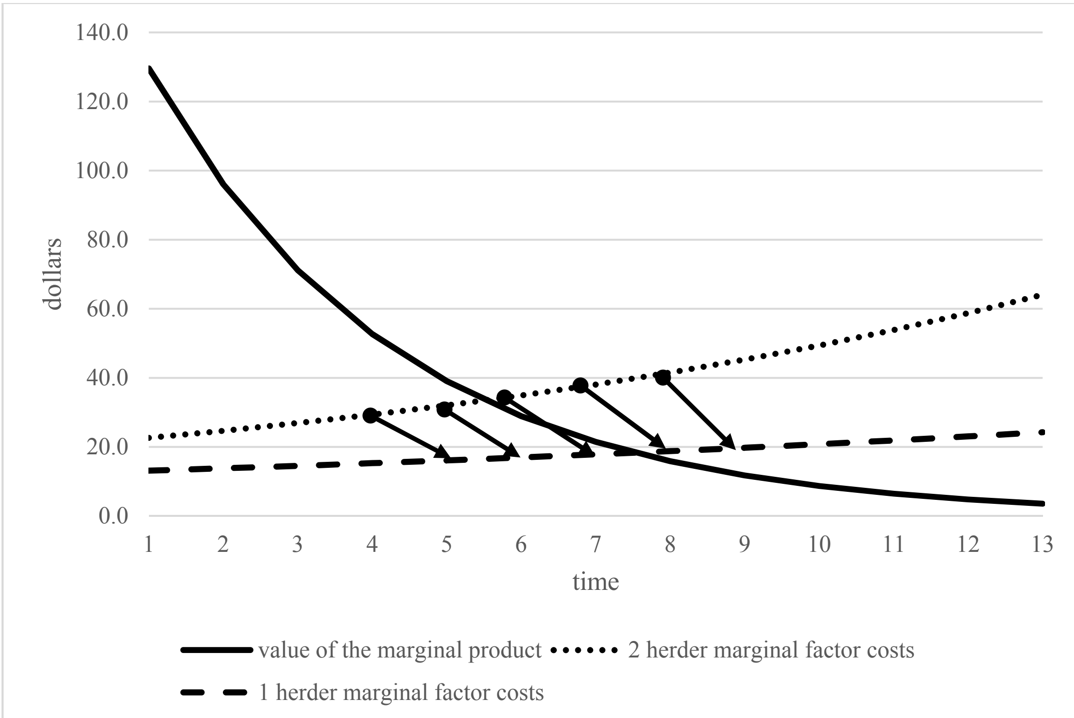

Figure 2: Dynamic Profits and Transition When One Herder Exits

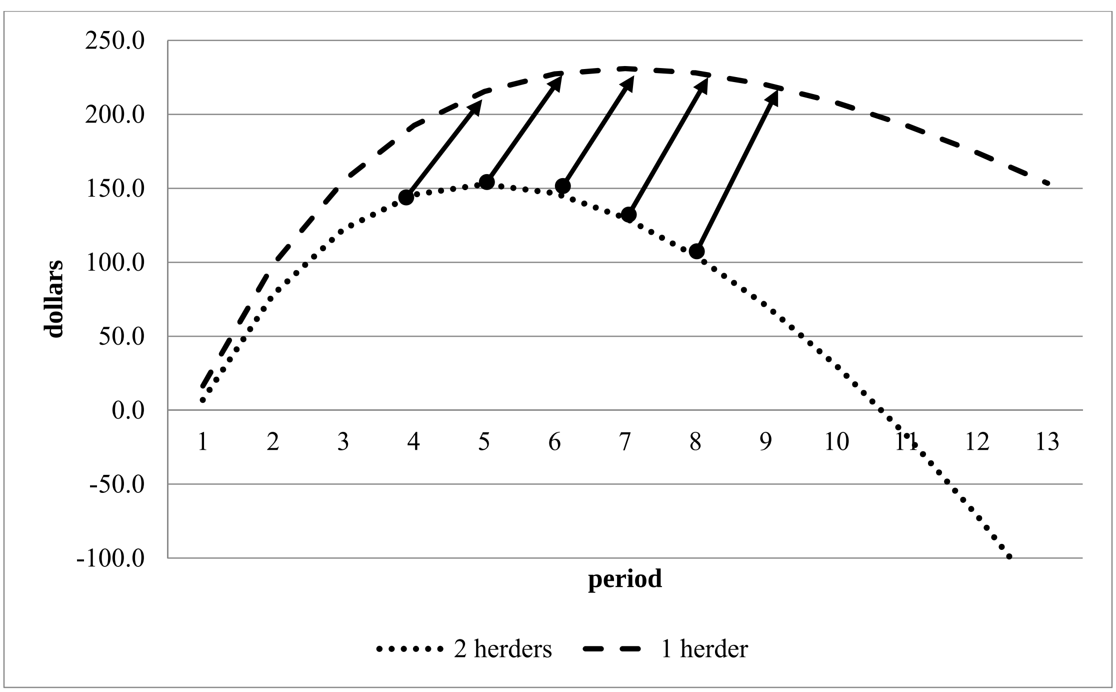

Figure 3. Period Payoffs and Mixed Strategy Sell {q, r}

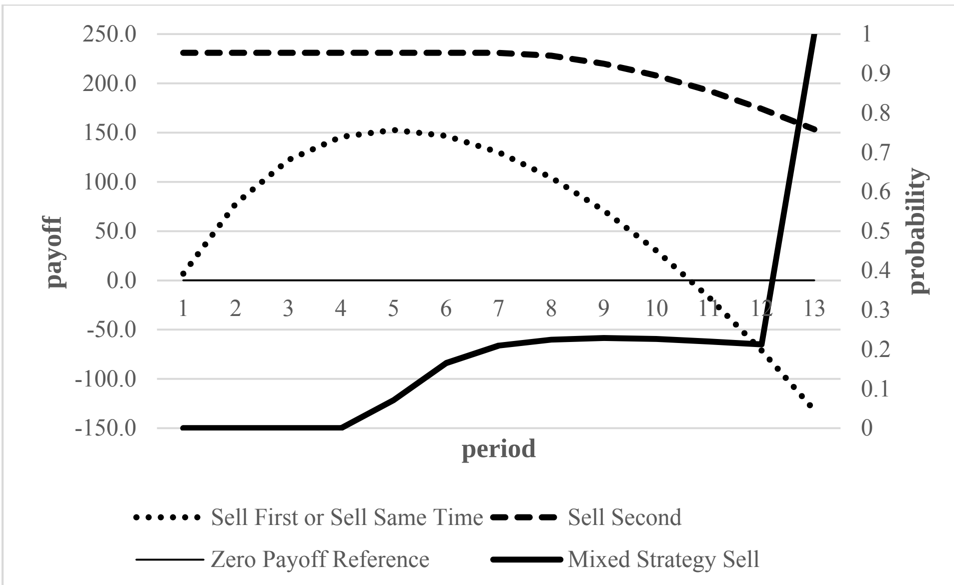

Figure 4. Period Value Differences between Selling First or Simultaneous and Selling Second

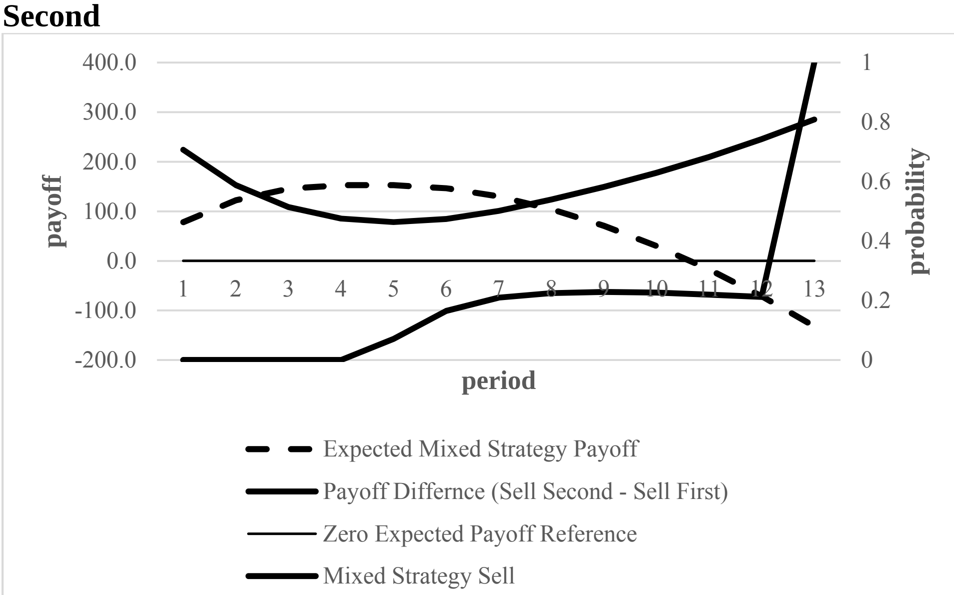

Figure 5. Seller Type Frequency Incentive to Sell