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EXPLAINING PARTICIPATION IN SPOT AND OPTIONS MARKETS FOR WATER

By

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Explaining Participation in Spot and Options Markets for Water[1]

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Introduction

Currently, agriculture accounts for the major share of water use in the U.S. However, demand for water outside agriculture has been steadily rising over time. Demanders include, agricultural transfers within agriculture, municipal, industrial, and environmental users. Despite a higher value of water to the outside users, there have been few transactions of water from the agriculture to the outsider users, thus creating a water shortage to the later (Gaffney 1997, Michelsen 2000, etc.).

Water transfers through markets have been advocated as a means of mitigating water-supply shortages to the outside users. However, various factors have limited the development of operational markets for water in the past. These include physical, financial, institutional limitations[2]. Young (1986) describes four basic ingredients of an institution that would make water markets viable- security, flexibility, certainty, and consideration of third party impacts. Even where the physical conditions have been optimal, significant institutional bottlenecks exist in the form of transaction costs and risks. Lund (1993) shows that the risk associated with the actual delivery of water, to the water buyer, matters and can be a significant factor in determining the success of water markets. Such risks of failure generally arise from court challenges posed by third parties who might be affected by such transfers. To the sellers of water, the fear of adverse consequences from trade may form the most significant hindrance to market participation[3]. Adverse impacts on the farmers from federally induced markets may have political fallouts too.

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[2] See Ranjan et al. (2004) for a detailed review of the water market related literature for the US.

[3] Most studies, however, have found little impact on the agricultural sector from water transfers. Howe et al. (1990) examine the impact from water transfers on the area of origin for a seven-county reach of the Arkansas River in southeastern Colorado. Their analysis involves an input-output based approach that

Market based approaches such as the 'options' and the 'spot' markets have been identified as the preferred instruments to facilitate this transaction as they offer various degrees of risk mitigation to the buyers and sellers of water.

Much of the water transfers currently occurs through spot markets. In the context of water, spot markets refer to *ad hoc* leasing of temporary water use rights in response to a water-supply restriction underway. Spot markets typically involve agricultural sellers and other irrigators, or other parties representing municipal or environmental interests. Some studies have emphasized the role of spot markets in facilitating water transactions as they allow more flexibility and generally do not cause severe third-party impacts. Saleth et al. (1991) assess how spot markets would be restricted to few participants in presence of third party impacts caused by the flow pattern of water. For example, if a water transaction between two parties infringes upon the original water rights of downstream users, the scope of water transactions may be limited. In presence of such thin spot markets**,** transactions may be characterized by bargaining, the outcome of which would be affected by such factors as the size of the bargaining units, the nature of water rights (equal sharing versus priority sharing), the nature of the bargaining mechanism, and the availability of information on the participants payoffs.

Of the two types, the spot market and the contingent market, the latter has been advocated to be of particular interest in various regards. Howitt (1998) makes the case

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incorporates both backward and forward linkages of the agriculture sector. They find that total losses to the agriculture sector from irrigation reductions are insignificant and easily accounted for by the gains to urban areas from increased water transfers.

On the other hand, Moore and Dinar (1995) come up with opposite conclusions. They design various models of input use involving two inputs- surface water and land- to test whether such factors might be treated as fixed by the farmers. Empirical models are estimated using data from western San Joaquin Valley of California. The model results indicate that farmers treat surface water as fixed input rather than a variable one, with significant implications for federal water policy, the Central Valley Project Improvement (CVP) Act.

for options markets by arguing that spot markets and the permanent-rights markets constitute two polar cases wherein risk is shifted from one party to the other. In case of spot markets, most of the risk is borne by the buyer due to the thin market characteristics of such transactions. In the case of permanent rights market, the seller of the rights needs to evaluate the value of his rights given current and expected future demands. The risk of selling the rights at a lower price than what may occur at sometime in the future is always there, especially if the seller is risk averse. These risks and uncertainties introduce significant transaction costs. He argues that options markets can help lower the risks arising from both supply and price uncertainties to both parties. Michelson and Young (1993) examine the role of water-supply options contracts in facilitating water markets. Under this kind of contract, owners of the water (farmers) do not give up rights to water and typically lose access to water only in the dry periods. A number of conditions must be satisfied in order for the option markets to work. Chief amongst them are reliability of water supplies (to ensure sufficient water during dry years and plenty during normal years), well defined property rights, ability of the seller of the water rights to temporarily suspend his operations, availability and knowledge of risks of drought, and attractiveness of option contract costs as compared to alternative costs of attaining water in dry years. The authors further cite features of the water market that distinguish it from other kind of options contracts. These include the temporary nature of the contract (transferring use Vs ownership rights), potential exercise of the option multiple times over the contract period, and exercise of option being supply- dependent rather than price dependent. They define the option value of water as the difference in the cost of the options contract and the next best alternative source of water.

In sum the spot and options markets serve the needs of both the buyers and sellers in terms of risk sharing and smoothing uncertainties in water demand and supply. However, despite such advantages offered by these markets, their development has been slow in the US so far. In certain cases, the success has been partial with one of the markets failing to materialize, thus posing significant challenges to participants in terms of risk sharing and supply insurance.

While options and spot markets have been promoted as a means to alleviate the water shortages faced by buyers, there are substantial risks to the farmers participating in these markets. These risks are a cause of significant concern to the federal agencies that are responsible for disaster mitigation for farmers. Federal promotion of such markets implicitly places the burden of adverse impacts of markets on such agencies. Such adverse consequences may primarily be dictated by the relative composition of participants between the spot and options markets. Spot markets offer higher rewards to the water sellers but also carry higher risks in terms of price fluctuations with them. Option markets help hedge against water price fluctuations but may severely affect the agricultural sector due to long term water commitments. Losses include forgone agricultural output from long term committed sale of water to the farmers, loss of employment and agricultural productivity and forward linkage effects that include the buyers of agricultural outputs[4].

[4] Some impacts of long term water transfers include loss of soil fertility due to prolonged periods of no-cultivation, invasion of fallow lands by alien species that might be costly to eradicate, increased waste water treatment costs, and reduced agricultural productive capacity (Howe 1997).

It is pertinent to understand the forces determining the relative success of the spot and options markets in order to access the burden to the federal agencies from adversely impacted farmers. A proper understanding of the underlying forces will also help predict the cases when one or both the markets fail to take off. While concerns to the farmers are justified, the value of water to buyers is much higher and successful functioning of options markets is an important concern for them. Early identification of option market failure may pave the way for alternate means to mitigating water shortages in certain areas.

In order to understand the relative participation between the spot and the options markets we need to account for the factors that affect decision making for the market participants. The risks arising from sale of water to the farmers constitute a significant element in their decisions to trade water. Such risks are affected by several factors that include the demand and supply side uncertainties, uncertain opportunity costs of water, etc. Profits are also affected by the size of the market that in turn is determined by the number of participants in the market, the elasticities of demand, etc. An individual farmer's choice between the spot and the option market is affected by his profitability considerations in the two markets. Market participation in such cases may involve incorporation of forward looking general equilibrium impacts into individual decisions. Such feedback calculations may determine and explain the relative success of one market over the other.

This paper addresses the dynamics between spot market transactions and option markets, where conditions permit market transactions for water. The paper develops two models (one for multiple farmer case and the other involving its application to two farmers case) that are used to examine producer participation choice between spot or option markets, under dynamic price and resource-supply conditions. The first model considers a collective of farmers of similar productivity. The second model extends the first model to a specific case of two farmers with differential productivity and strategic behavior. Simulations are defined to assess the effect of key variables on market participation, including agricultural water demand, the price of water, land supply, price elasticity of demand for agricultural output, and the productivity of agriculture. Factors resulting in the failure of markets, where incentives are insufficient to promote participation, are also evaluated. Policy implications and conclusions follow.

Model

In this model we explore the interaction between a large urban buyer and a group of homogenous farmers, a typical situation characterizing water exchange in such markets, in a general equilibrium framework involving two time periods. In the first period, the buyer offers an option and exercise price for water purchase in the options market. Farmers decide between entering the option market and waiting for the spot market. In the second period water supply is known and the spot market evolves to meet the buyer's residual demand. However, the decision to enter one or the other market needs to be taken at the beginning of period one based upon the expected profits in the two markets.

Benefits from spot or options market sale of water are affected by the collective choice of the farming community. For instance, if farmers expect the future spot prices to be high, they would hold back their water and not enter the options market. This in turn would lead to a glut of water in the spot marker thus lowering its price. Similarly, the relative composition of farmers between the spot market and the options market would determine the total supply of agricultural output. If the demand for agricultural output is price elastic, profitability in the agricultural market would depend upon the distribution of farmers between the spot and options market. Farmers who sell their water in the options market would have less or no flexibility to use it for agricultural purposes in a dry year, while farmers in the spot market could decide the optimal allocation between the spot market sales and agricultural use water based on the marginal revenue criterion. Profitability from spot and options market participation would depend upon the expectation of future water supply, which would determine the availability of water for agricultural uses both in the spot and options market. A dry year would raise the spot market benefits whereas a wet year would raise the options market profitability relative to the spot market. Therefore, in a competitive equilibrium, the expected benefits in the two markets would be equalized. This is the framework adopted for the model below.

Let there be N farmers, each farmer with one unit of surface water right (w) and L units of land. Farmers have a choice of selecting between the spot market and the options market. If they decide to enter the options market they must deliver the water to the urban buyer at the predetermined options and exercise prices. There is, however, some uncertainty over the supply of surface water. This uncertainty is denoted by a probability density function $f(s)$, with $1 > s > 0$ where s is the 'realized' sale of water to the urban buyer in wake of a drought. The idea is that, though the farmer receives an option price for the sale of his entire 1 unit of water, the actual amount of water that is sold is determined by availability of water in a dry year. For example, if the farmer receives only half of his annual supply of water, he can deliver only that much to the buyer. Also, the farmer has groundwater supply in a wet year equal to *G* units, which too is affected by the drought conditions. Thus, if in a dry year the surface water supply to the farmer is *s*, then his groundwater supply is *Gs*[5]. Let the production function for the agricultural commodity *x* for the farmer be denoted by:

$$x = Aw^{\gamma} L^{1-\gamma} \tag{1}$$

where γ is the share of water in the total output. Let *h* be the option price offered by the urban buyer, *k* the exercise price and let the urban demand for water be:

$$Q = p^{-\alpha} \text{ or, } p = Q^{-1/\alpha} \tag{2}$$

where *P* is the price of water in the water market and α the elasticity of demand. Let *u* be the price of water paid by the farmers for the use of surface water. Let *n* be the number of farmers who decide to enter the options market. The expected supply of water in the options market would be:

$$E(SS(options)) = n\int_0^1 sf(s)ds \tag{3}$$

Therefore, the expected supply of water in the spot market would be:

$$E(SS(spot)) = (N-n)\int_0^1 sf(s)ds \tag{4}$$

The residual urban demand for water in the spot market would be:

$$Q = p^{-\alpha} - n\int_0^1 sf(s)ds \tag{5}$$

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[5] Groundwater may be affected disproportionally, however this assumption does not lead to any loss of generality.

Demand for water for agricultural uses in the spot market would be given by the equality between marginal productivity of water and the price of water:

(6) $$MVP_w = A\gamma L^{1-\gamma}(w + \int_0^1 Gsf(s)ds)^{\gamma-1} z = p \Rightarrow w = (\frac{p}{zA\gamma L^{1-\gamma}})^{\frac{1}{\gamma-1}} - \int_0^1 Gsf(s)ds$$

where z is the price of the agricultural output and the w is the demand for surface water. Note that the expected marginal product should include the expected output from use of groundwater too. Therefore, the total expected demand for water in the spot market is given by:

(7) $$E(DD(spot)) = (\frac{p}{zA\gamma L^{1-\gamma}})^{\frac{1}{\gamma-1}} - \int_0^1 Gsf(s)ds + p^{-\alpha} - n\int_0^1 sf(s)ds$$

Water market would clear when expected demand equals expected supply:

(8)

$$E(SS(spot)) = (N-n)\int_0^1 sf(s)ds =$$

$$DD(spot) = (N-n)((\frac{p}{zA\gamma L^{1-\gamma}})^{\frac{1}{\gamma-1}} - \int_0^1 Gsf(s)ds) + p^{-\alpha} - n\int_0^1 sf(s)ds$$

The above equation would lead to the solution of price of water P in terms of all other variables as:

(9) $$p^* = p(A, N, n, \alpha, z, \gamma, L, f(s), s, G)$$

Expected agricultural output in the spot market would be given by:

(10) $$x(spot) = (N-n)AL^{1-\gamma}(\,(\frac{p^*}{zA\gamma L^{1-\gamma}})^{\frac{\gamma}{\gamma-1}})$$

Total expected agricultural output in the spot market and the options market combined would be:

(11) $$x(option) = (N-n)AL^{1-\gamma}\left(\left(\frac{p^*}{zA\gamma L^{1-\gamma}}\right)^{\frac{\gamma}{\gamma-1}}\right) + nAL^{1-\gamma}\left(\int_0^1 Gs\, f(s)ds\right)^{\gamma}$$

Agriculture market clears when demand equals supply. Let the demand for agricultural output be equal to:

(12) $$z^{-\beta}$$

where β is the price elasticity of agricultural demand. Therefore, the price of agricultural produce would be solved by equating the demand and the supply as:

(13) $$(N-n)AL^{1-\gamma}\left(\left(\frac{p^*}{zA\gamma L^{1-\gamma}}\right)^{\frac{\gamma}{\gamma-1}}\right) + nAL^{1-\gamma}\left(\int_0^1 (Gs)\ f(s)ds\right)^{\gamma} = z^{-\beta}$$

This gives the price of the agricultural commodity as:

(14) $$z^* = Z(A, L, N, n, \alpha, \beta, \gamma, f(s), G)$$

Profits from spot market participation would be sum of expected agricultural profits and the profits from spot market sale of water to the urban buyer:

(14)

$$\pi(spot) = (N-n)AL^{1-\gamma} z\left(\frac{p^*}{zA\gamma L^{1-\gamma}}\right)^{\frac{\gamma}{\gamma-1}} - (N-n)rL - (N-n)\int_0^1 (u + d^*G)sf(s)ds +$$

$$(N-n)p^*\left(\int_0^1 f(s)ds - \left(\left(\frac{p^*}{zA\gamma L^{1-\gamma}}\right)^{\frac{1}{\gamma-1}} - \int_0^1 Gsf(s)ds\right)\right)$$

where r is the rent on agricultural land

Now let's get back to the options market. The expected profits in the options market is the sum of the option and the exercise price and the net benefits from the agricultural output:

(15) $$h + \int_0^1 ksf(s)ds + zL^{\gamma-1}\left(\int_0^1 Gs\right)^{\gamma} A - rl - \int_0^1 (u + d^*G)s)\, f(s)ds$$

Farmers would weigh the profits from the options market to the profits from the spot market in deciding between the two. Therefore, under equilibrium the two would be equal:

(16)

$$\pi(spot) = AL^{1-\gamma} z(\frac{p*}{zA\gamma L^{1-\gamma}})^{\frac{\gamma}{\gamma-1}} - rL - \int_0^1 usf(s)ds + p*(\int_0^1 f(s)ds - ((\frac{p*}{zA\gamma L^{1-\gamma}})^{\frac{1}{\gamma-1}} - \int_0^1 Gsf(s)ds)) =$$

$$h + zL^{\gamma-1}(\int_0^1 Gs)^{\gamma} A - rl - \int_0^1 (u + d*G)s) f(s)ds + \int_0^1 ksf(s)ds$$

Solving (16) would lead to *n*, the number of farmers who decide to enter the options market, and (*N*-*n*), the number of farmers who decide to enter the spot market.

The above approach assumes that the in an equilibrium, both the markets will have some participants in them. However, in reality, it may happen that one of the two (or both) markets fail to attract any participants. This will lead to a concentration of all farmers into one (or none) of the markets. This would happen when the profits to a single farmer in one of the markets, when all the participants decide to enter it, exceed those from the other when he is the only entrant in that market. Intuitively, if the expected supply of future water is low and the productivity in agriculture is high with a low elasticity of demand (such as for an export good), farmers would stay away from the options market as it would reduce the water available to them in a dry year. This same condition would also lead to a spot market failure if the marginal revenue product of water is higher than the existing price of water in the spot market. In Appendix A-1 we derive these conditions for the failure of either of the markets.

The above equations are analytically intractable due to the exponential terms in the equations and we need to put more structure on the model in order to perform numerical simulations. We assume that the production function for the agricultural commodity is Cobb-Douglas and the uncertainty associated with water supply has a uniform distribution. Accordingly expected profits in the options market are (solving (15)) given by:

(17) $$(h + zAL^{1-\gamma}(G/2)^{\gamma} - rL - \frac{u}{2} + K/2)$$

Expected supply of water in the options market is given by solving (3):

(18) E(supply in the options market) = $\frac{n}{2}$

Expected residual demand in the spot market is given by solving (5):

(19) $$Q = p^{-\alpha} - \frac{n}{2}$$

Expected supply of water in the spot market is given by solving (4):

(20) $$\frac{N-n}{2}$$

Spot market demand for water to be used in the Ag sector is given by solving (6). Market in water clears when demand for water equals the supply of water:

(21)

$$E(SS(spot)) = \frac{N-n}{2} =$$

$$DD(spot) = (N-n)((\frac{p}{zA\gamma L^{1-\gamma}})^{\frac{1}{\gamma-1}} - G/2) + p^{-\alpha} - \frac{n}{2}$$

Equation (21) would give P* the market clearing price of water. Solving (13) we get the market clearing condition in the agricultural output sector:

(22) $$(N-n)AL^{1-\gamma}\left(\left(\frac{p^*}{zA\gamma L^{1-\gamma}}\right)^{\frac{\gamma}{\gamma-1}}\right)+nAL^{1-\gamma}(G/2)^{\gamma}= z^{-\beta}$$

Finally, the market clearing condition between the spot and options market is given by:

(23)

$$\pi(spot)=AL^{1-\gamma}z\left(\frac{p^*}{zA\gamma L^{1-\gamma}}\right)^{\frac{\gamma}{\gamma-1}}-rL-\frac{u}{2}-d*G/2+$$

$$p*\left(\frac{1}{2}-\left(\frac{p^*}{zA\gamma L^{1-\gamma}}\right)^{\frac{1}{\gamma-1}}+G/2\right)=(h+zAL^{1-\gamma}(G/2)^{\gamma}-rL-\frac{u}{2}-d*G/2+K/2)$$

Solution of (21)-(23) simultaneously would yield the prices and the distribution of farmers between the two markets. Next, we solve the above equations using MATLAB to derive the expected constitution of farmers between the two markets. We also perform numerical simulations by means of parameter variations to understand the impact of key parameters on deciding market composition. Model parameters are presented in Appendix A-2.

Results

The results of the simulations are depicted through figures below. Figure 1 shows the effect of market size on prices of water and agricultural output in the base case. Predictably, the prices fall with an increase in the number of farmers (INSERT FIGURE HERE). However, the distribution of agricultural output in the two markets goes in opposite directions with an increase in the market size. More output is produced in the option market as compared to the spot market as the number of farmers increase. This is due to the fact that an increase in the number of farmers raises the expected supply of agricultural commodity lowering its expected price relative to the price of water in the option market. Whereas, when the number of farmers is lower than the base case (10 farmers), the output in the spot market is higher than the option market due to the high returns from sale of agricultural commodity. This is primarily due to the fact that more farmers prefer to enter the spot market and use water in agriculture rather than lose it in the option market. This is depicted in figure 2 below (INSERT FIGURE HERE). As the number of farmers increases, the concentration of farmers in the option market rises whereas it falls in the spot market. Figure 3 shows water transaction in the spot market (INSERT FIGURE HERE). Note that both the spot market sale and use of water are high when the number of farmers is low. Less number of farmers means a lower supply of water in the urban market and a lower output of agricultural commodity. As a consequence prices are high in both the markets. Figure 4 looks at the effect of varying the share of water (gamma) in the production function of farmers (INSERT FIGURE HERE). Increasing the share of water also has the adverse consequences of decreasing the share of land in the production function. If land is available in plenty (relatively) then the total output may go down. This is what happens in the example chosen above. As gamma is increased, more and more people opt for the spot market where they could purchase water for agricultural uses. As a consequence of reduced output in agriculture and increased demand for water prices go up for both water and agricultural produce. The sustainable equilibrium thus leads to increasing concentration in the spot market with rise in gamma. These effects are depicted in figures 4 and 5 (INSERT FIGURE HERE). Figure 6 depicts the impact of demand elasticity of agricultural output on the distribution of farmers and the agricultural outputs in the two markets[6] (INSERT FIGURE HERE). An increase in the elasticity of demand raises the concentration in the spot market as

[6] The parameter beta is the inverse of the agricultural elasticity of demand; therefore higher beta would imply lower elasticity.

more output could be sold without lowering the price, thus leading to higher revenues. As a consequence, output rises in the spot market and falls in the options market. Farmers would enter the spot market with the hope of buying more water and making large profits. The consequential effects on expected water and agricultural prices are depicted in figure 7 (INSERT FIGURE HERE). Note that both water and agricultural prices rise as the elasticity of demand increases. Increase in water demand raises water prices for the urban users. Figure 8 looks at the impact of increased land availability on the distribution of farmers (INSERT FIGURE HERE). The impact on the distribution is felt through the decrease in price of agricultural commodity due to increased output from more land availability. Thus, option market becomes more attractive compared to the spot market. Price effects and the distribution of water between agricultural and urban uses is depicted in figure 9. Similar effects are felt by increasing the overall productivity of the farmer through the parameter (A) and are depicted in 10 and 11 (INSERT FIGURES HERE).

A Case of Productivity Differential

Let's next consider the case of productivity differential across farmers. Assume that farmers differ in their productivity (without putting any further structure on their distribution). Whether the highly productive farmers would decide to enter the spot or the options market would depend upon several factors. To simplify this further let's assume that there are only two farmers, one with high productivity and the other with low productivity[7]. This setting will allow us to explore the conditions under which it is optimal for a typical farmer to prefer one market to another. It will also allow us to

[7] One could also assume a uniform distribution of productivity; however, the analysis would be blurred in such a case. For instance, a few farmers with large productivity may have similar implications for the market as a large number of farmers with lower productivity.

derive conditions under which one (both) of the markets may fail. Since we have only two farmers, we need to allow for strategic behavior. We model this problem in a game theoretic setting where both the farmers decide simultaneously between the spot and the options market. Let the production function for the farmer with low productivity (farmer 1) be:

(24) $x = A_1 L^{1-\gamma} W^{\gamma}$

and the production function for the high productivity (farmer 2) be:

(25) $x = A_2 L^{1-\gamma} W^{\gamma}$

There are four possible payoffs to each of the farmers depending upon what the other does. Let these be represented as:

Matrix of Payoffs:	Farmer 2 (options market)	Farmer 2 (spot market)
Farmer 1(options market)	$(\pi_{1o}\pi_{2o})$	$(\pi_{1o}\pi_{2s})$
Farmer 1 (spot market)	$(\pi_{1s}\pi_{2o})$	$(\pi_{1s}\pi_{2s})$

where the first one is the payoff to the farmers when both of them decide to enter the spot market and so on. Next we derive the payoffs. When both the farmers decide to enter the spot market, there would be no water sold in the options market. The demand for water for water in the spot market would consist of the agricultural demand plus the urban demand. The agricultural demand is given by:

(26) $((\frac{p}{zA_1\gamma L^{1-\gamma}})^{\frac{1}{\gamma-1}} - \int_0^1 Gsf(s)ds)$ for farmer 1 and $((\frac{p}{zA_2\gamma L^{1-\gamma}})^{\frac{1}{\gamma-1}} - \int_0^1 Gsf(s)ds)$

for farmer 2.

Total demand including the agricultural demand is given by:

$$(27)\qquad \left(\frac{p}{zA_1\gamma L^{1-\gamma}}\right)^{\frac{1}{\gamma-1}} - 2\int_0^1 Gsf(s)ds) + \left(\frac{p}{zA_2\gamma L^{1-\gamma}}\right)^{\frac{1}{\gamma-1}} + P^{-\alpha}$$

Water market clearing condition:

$$(28)\qquad \left(\frac{p}{zA_1\gamma L^{1-\gamma}}\right)^{\frac{1}{\gamma-1}} - 2\int_0^1 Gsf(s)ds) + \left(\frac{p}{zA_2\gamma L^{1-\gamma}}\right)^{\frac{1}{\gamma-1}} + P^{-\alpha} = 2\int_0^1 sf(s)ds$$

This would lead to price of water p^{ss}. The agricultural market clearing condition is given by:

$$(29)\qquad A_1\left(\frac{p}{zA_1\gamma L^{1-\gamma}}\right)^{\frac{\gamma}{\gamma-1}} L^{1-\gamma} + A_2\left(\frac{p}{zA_2\gamma L^{1-\gamma}}\right)^{\frac{\gamma}{\gamma-1}} L^{1-\gamma} = z^{-\beta}$$

This would yield the price of agricultural commodity. The profits for the two farmers can then be derived as:

(30)

$$(\pi_{1s},\pi_{2s}) = \left\{A_1\left(\frac{p^*}{z^{ss}A_1\gamma L^{1-\gamma}}\right)^{\frac{\gamma}{\gamma-1}} L^{1-\gamma} z^{ss} - rL - \int_0^1 (u+d*G)sf(s)ds + p*((\int_0^1 sf(s)ds - \left(\frac{p}{z^{ss}A_1\gamma L^{1-\gamma}}\right)^{\frac{1}{\gamma-1}} + \int_0^1 Gsf(s)ds)\right\},$$
$$\left\{A_{21}\left(\frac{p^*}{z^{ss}A_2\gamma L^{1-\gamma}}\right)^{\frac{\gamma}{\gamma-1}} L^{1-\gamma} z^{ss} - rL - \int_0^1 (u+d*G)sf(s)ds + p*((\int_0^1 sf(s)ds - \left(\frac{p}{z^{ss}A_2\gamma L^{1-\gamma}}\right)^{\frac{1}{\gamma-1}} + \int_0^1 Gsf(s)ds)\right\}$$

When both the farmers decide to enter the option market, their payoffs could be derived as:

(31)

$$(\pi_{1o},\pi_{2o}) = \begin{array}{l}\left\{h + \int_0^1 (z^{oo}(L^{\gamma-1}(Gs)^{\gamma} A_1 - rl - (u+d*G)s)f(s)ds + \int_0^1 ksf(s)ds\right\}, \\ \left\{h + \int_0^1 (z^{oo}(L^{\gamma-1}(Gs)^{\gamma} A_2 - rl - (u+d*G)s)f(s)ds + \int_0^1 ksf(s)ds\right\}\end{array}$$

When the high productivity farmer decides to enter the spot market and the low productivity farmer the option market, the residual demand for water in the spot market can be derived as:

(32)

$$(\frac{p}{zA_1\gamma L^{1-\gamma}})^{\frac{1}{\gamma-1}} - \int_0^1 Gsf(s)ds) + P^{-\alpha} - \int_0^1 sf(s)ds = \int_0^1 sf(s)ds$$

This would lead to a price of water as p^{so}. The price of agricultural output z^{so} could be similarly derived as:

(33) $$A_1(\frac{p}{z^{so}A_1\gamma L^{1-\gamma}})^{\frac{\gamma}{\gamma-1}} L^{1-\gamma} + A_2 L^{1-\gamma}(\int_0^1 Gsf(s)ds)^{\gamma} = z^{-\beta}$$

The payoffs to the two farmers are:

(34) $(\pi_{1s}, \pi_{2o}) =$

$$\left\{A_1(\frac{p}{z^{so}A_1\gamma L^{1-\gamma}})^{\frac{\gamma}{\gamma-1}} L^{1-\gamma} - rL - \int_0^1 (u + d*G)sf(s)ds + p^{so(}(\int_0^1 sf(s)ds - (\frac{p}{z^{so}A_1\gamma L^{1-\gamma}})^{\frac{1}{\gamma-1}} + \int_0^1 Gsf(s)ds))\right\},$$
$$\left\{h + A_2 L^{1-\gamma}(\int_0^1 Gsf(s)ds)^{\gamma} z^{so} - rL - \int_0^1 (u + d*G)sf(s)ds + k\int_0^1 sf(s)ds\right\}$$

Similarly, the payoffs when farmer 1 enters the options market are given by:

(35) $(\pi_{1o}, \pi_{2s}) =$

$$\left\{h + A_1 L^{1-\gamma}(\int_0^1 Gsf(s)ds)^{\gamma} z^{os} - rL - \int_0^1 (u + d*G)sf(s)ds + k\int_0^1 sf(s)ds\right\},$$
$$\left\{A_{21}(\frac{p}{z^{os}A_1\gamma L^{1-\gamma}})^{\frac{\gamma}{\gamma-1}} L^{1-\gamma} - rL - \int_0^1 (u + d*G)sf(s)ds + p^{os}(\int_0^1 sf(s)ds - (\frac{p}{z^{os}A_2\gamma L^{1-\gamma}})^{\frac{1}{\gamma-1}} + \int_0^1 Gsf(s)ds))\right\}$$

Using parameter values in table 2 in appendix A-2, we perform simulations to look at cases for successful and failed markets[8].

Results for the Two Farmers Case

The Base case as shown in the Table 1 (INSERT TABLE 1 HERE), leads to a spot market failure. The parameters are chosen such that it is a dominant strategy for both the farmers to enter the option market. This condition is made feasible by a high option value and exercise price combined with demand for water in the urban market. Also observe that the high productivity farmer makes higher profits and is less adversely affected in all four of the scenarios in the payoff matrix. Table 2 (INSERT TABLE 2 HERE) gives an example where the option market fails. This is made possible by selecting a higher water demand curve (through parameter P0). The influence of productivity differential is more clearly brought out by Table 3 (INSERT TABLE 3 HERE), which depicts a case of low option value and exercise price. In such as case neither of the markets are dominated by the other. There are two equilibriums involving both farmers going into the spot market or the option market. However, none of them could be ruled out over the other. Option market for both yields higher payoffs than spot market; however, there is no way to avoid the inferior outcome of both settling for the spot market without pre-decision communication. This may explain, why it is possible for options market to fail even under favorable circumstances when the strategic behavior amongst farmers is taken into consideration. Finally, Table 4 looks at the impact of a much higher productivity differential on the market participation outcomes (INSERT

[8] Formal derivations of the conditions for market failure for the two farmer case are available upon request.

TABLE 1 HERE). Contrary to intuition, farmer one who has low productivity gains more from spot market participation than option market participation. One would expect that when water has lower yields in agriculture, entering the options market would be more beneficial. However, when the effects of the other participant on water and agricultural prices are incorporated, this may not hold. Farmer two, who has a comparatively higher agricultural yield from water, has options market as his dominant strategy. This is so as agricultural prices are highly susceptible to agricultural output, and therefore farmer two being the larger producer of it is able to contribute more towards its fall. Farmer one on the other hand benefits from option market participation of farmer two by opting out of it and waiting for the spot market where he sells his water to the urban buyer. Note that being not able to produce much from water inhibits his ability to benefit from high agricultural prices and therefore he prefers to stay in the spot market even though both farmers entering the option market raises agricultural prices significantly. As a result, spot market is the dominant strategy for him.

Conclusion

This paper models the issue of relative success of spot and option markets for water. The issue is important and timely as the relative excess of water in the agricultural sector compared to outside needs makes it imperative that all available market mechanisms be exercised. The analysis performed in this paper is relevant due to several reasons. First, it highlights situations under which one or both the markets may fail. An understanding of such situations may prepare the policy makers in advance for ensuing water shortages. Second, it may provide a framework to assess the success or failure of water market introductions in the past. Third, the prediction of relative participation may help in guiding public policies that are aimed at mitigating the consequences of water markets to the farmers. For instance, if contingent markets may have long-term impacts such as loss in productivity and employment, etc., a relative composition of farmers between the two markets would help decide the nature of other policies such as subsidies and taxes in order to induce the right participation that optimizes the social welfare.

The approach adopted in this paper provides deeper insights into the observed behavior of farmers, which may not be easily obvious. The N farmer case model provides numerous valuable insights into the equilibrium outcome market composition under uncertainty and forward-looking behavior. For instance, if the agricultural demand is high and expected future supply of water low, farmers would like to hold off their water from the options market and use it in agricultural production or sell it in the spot market. However, when the simultaneous impacts of homogenous farmers faced with similar situations are concerned, the response may not be so. This is due to the fact that as the number of farmers who plan to enter the spot market rises, the profits in agriculture may fall depending upon the price elasticity of demand. Profits in the option market would rise, on the other hand, with fewer participants remaining in that sector. The equilibrium distribution of participants would be achieved when the profits to the marginal farmer in the two markets are equalized. Conditions are also derived for complete failure of either of the markets. The analysis is further, extended to consider the impact of heterogeneity amongst the sellers on their distribution between the spot and the options markets. The analytical findings are further enriched through numerical simulations. The strategic behavior amongst farmers plays a much more significant role when the number of participants is low. This is apparent from the two-farmer case where Nash equilibrium may involve both superior and inferior outcomes. In such a case there is no way to predict the outcome unless public policies induce collaboration for greater common good.

The analysis of the model must not be taken at its face value as ground conditions may vary. Unfortunately there is not much empirical evidence to test our model. It is hoped that the insights from this study would provide reasonable predictions of the relative participations in the two markets, (including the cases when either of the markets may fail entirely) based upon the key variables such as water supply uncertainty, market size and strategic behavior, thereby aiding policy makers with valuable information to provide adequate institutional settings and supplementary policies aimed at mitigating the adverse consequences of water trade to the farmers and the environment.

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Appendix A-1

Let's first look at the conditions for the spot market failure. Let's assume that (N-1) farmers have already indicated to enter the options market. The spot market would fail if the profits from entering the options market to the last farmer, who is yet to decide, are higher than the expected profits from entering the spot market. The price in the options market would be:

(A) $$z = \left\{ NAL^{1-\gamma} (\int_0^1 Gsf(s)ds)^{\gamma} \right\}^{-1/\beta}$$

Therefore, his expected profits in the options market are:

(B) $$\left\{ NAL^{1-\gamma} (\int_0^1 Gsf(s)ds)^{\gamma} \right\}^{-1/\beta} AL^{1-\gamma} (\int_0^1 Gsf(s)ds)^{\gamma} - rL - (u + d*G)\int_0^1 sf(s)ds + k\int_0^1 f(s)ds$$

Now, let's look at the picture in the spot market. He would be the only entrant in the spot market. Therefore, the water market would clear when his demand for agricultural use plus the urban demand equal the total expected supply of water. That is:

(C) $$(\frac{p}{zA\gamma L^{1-\gamma}})^{\frac{1}{\gamma-1}} - \int_0^1 Gsf(s)ds) + p^{-\alpha} - (N-1)\int_0^1 sf(s)ds = \int_0^1 sf(s)ds$$

This would lead to a price of water $p^{spotfailure}$ in terms of the price of agricultural commodity $z^{spotfailure}$ and other parameters. The agricultural market would clear when:

(D) $$AL^{1-\gamma} (\ (\frac{p*}{zA\gamma L^{1-\gamma}})^{\frac{\gamma}{\gamma-1}}) + (N-1)\int_0^1 AL^{1-\gamma} (Gs)^{\gamma} f(s)ds = z^{-\beta}$$

Solving which we can get $z^{spotfailure}$. Next we derive the profits in the spot market to this farmer as:

(E)
$$\pi(spot) = AL^{1-\gamma} z\left(\frac{p^{spotfailure}}{z^{spotfailure} A\gamma L^{1-\gamma}}\right)^{\frac{\gamma}{\gamma-1}} - rL - \int_0^1 (u + d * G) sf(s)ds +$$
$$p^{spotfailure}\left(\int_0^1 f(s)ds - \left(\frac{p^{spotfailure}}{z^{spotfailure} A\gamma L^{1-\gamma}}\right)^{\frac{1}{\gamma-1}} + \int_0^1 Gsf(s)ds\right)$$

If we are interested in the parameters such as elasticities of demand for water and the agricultural commodity, we could derive a relationship between the two that would divide farmer's decision space into two regions; on one side of which spot market becomes attractive and on the other the options market. This would be given by:

(F)
$$\left\{NAL^{1-\gamma}\left(\int_0^1 Gsf(s)ds\right)^{\gamma}\right\}^{-1/\beta} AL^{1-\gamma}\left(\int_0^1 Gsf(s)ds\right)^{\gamma} - rL - (u + d * G)\int_0^1 f(s)ds + k\int_0^1 f(s)ds$$

$$>$$

$$\pi(spot) = AL^{1-\gamma} z\left(\frac{p^{spotfailure}}{z^{spotfailure} A\gamma L^{1-\gamma}}\right)^{\frac{\gamma}{\gamma-1}} - rL - \int_0^1 (u + d * G) sf(s)ds +$$
$$p^{spotfailure}\left(\int_0^1 f(s)ds - \left(\frac{p^{spotfailure}}{z^{spotfailure} A\gamma L^{1-\gamma}}\right)^{\frac{1}{\gamma-1}} + \int_0^1 Gsf(s)ds\right)$$

Similarly spot market failure conditions could be derived as follows:

Demand for water in the spot market would be:

(G)
$$(N-1)\left(\left(\frac{p}{zA\gamma L^{1-\gamma}}\right)^{\frac{1}{\gamma-1}} - \int_0^1 Gsf(s)ds\right) + p^{-\alpha} - \int_0^1 sf(s)ds = (N-1)\int_0^1 sf(s)ds$$

The agricultural market would clear when:

(H)
$$(N-1)AL^{1-\gamma}\left(\left(\frac{p*}{zA\gamma L^{1-\gamma}}\right)^{\frac{\gamma}{\gamma-1}}\right) + \int_0^1 AL^{1-\gamma}(Gs)^{\gamma} f(s)ds = z^{-\beta}$$

Next we derive the profits in the spot market to this farmer as:

(I)

$$\pi(spot) = AL^{1-\gamma} z\left(\frac{p^{optionfailure}}{z^{optionfailure} A\gamma L^{1-\gamma}}\right)^{\frac{\gamma}{\gamma-1}} - rL - \int_0^1 (u + d*G)sf(s)ds + p^{optionfailure}\left(\int_0^1 f(s)ds - \left(\frac{p^{optionfailure}}{z^{optionfailure} A\gamma L^{1-\gamma}}\right)^{\frac{1}{\gamma-1}} + \int_0^1 Gsf(s)ds\right)$$

His expected profits in the options market are:

(J)

$$z^{optionfailure} AL^{1-\gamma} \int_0^1 Gsf(s)ds)^{\gamma} - rL - u\int_0^1 f(s)ds + k\int_0^1 f(s)ds$$

The condition for option market failure, then, is :

(K)

$$\pi(spot) = AL^{1-\gamma} z\left(\frac{p^{optionfailure}}{z^{optionfailure} A\gamma L^{1-\gamma}}\right)^{\frac{\gamma}{\gamma-1}} - rL - \int_0^1 (u + d*G)sf(s)ds + p^{optionfailure}\left(\int_0^1 f(s)ds - \left(\frac{p^{optionfailure}}{z^{optionfailure} A\gamma L^{1-\gamma}}\right)^{\frac{1}{\gamma-1}} + \int_0^1 Gsf(s)ds\right) > z^{optionfailure} AL^{1-\gamma} \left(\int_0^1 Gsf(s)ds\right)^{\gamma} - rL - (u + d*G)\int_0^1 f(s)ds + k\int_0^1 f(s)ds$$

Appendix A-2

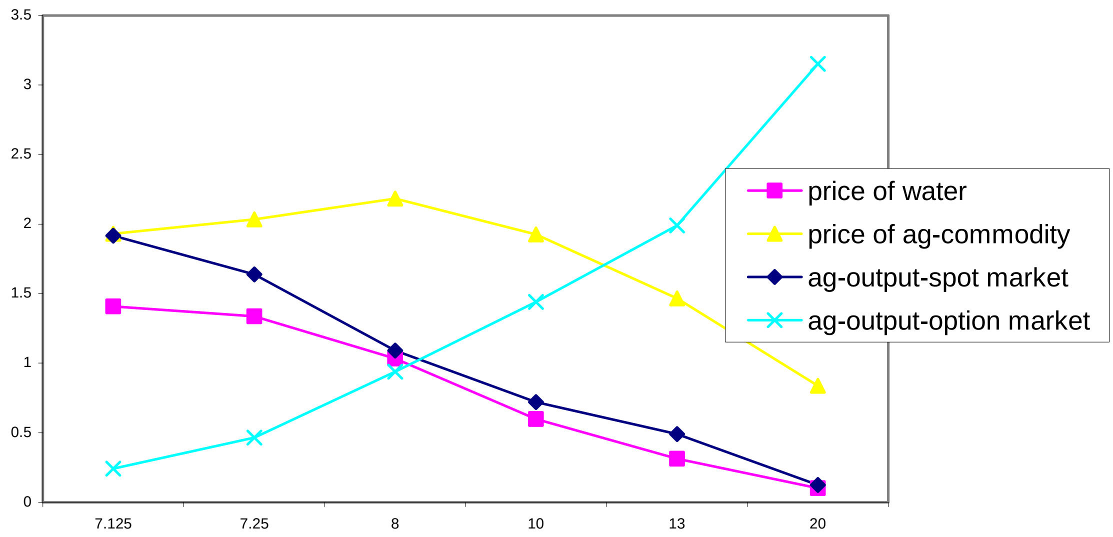
Model Parameters for the N Farmers Case

N	γ	α	β	L	G	A	$P0$	$z0$	u	d	k	r	h
10	.5	.5	.5	2	.1	.5	3	3	1.1	1.2	1.5	.1	.05

Model Parameters for the Two Farmers Case

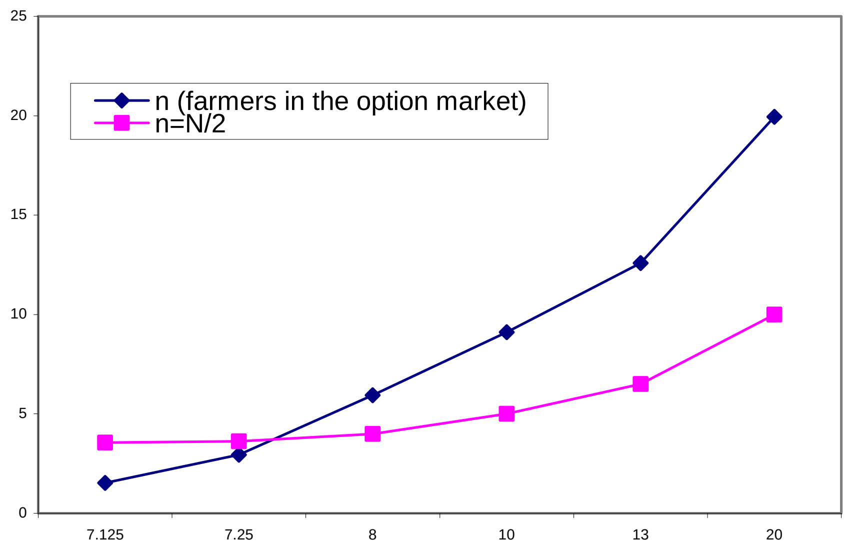
N	γ	α	β	L	G	$A1$	$A2$	$P0$	$z0$	u	d	k	r	h
2	.5	.5	.5	2	.5	.4	.6	.3	.9	1.1	1.2	1.5	.1	.05

Figure 1: Base Case--prices



N (total numner of farmers)

Figure 2: Base Case--n (farmers in the option market)



N (total numbers of farmers)

Figure 3: Base Case--Water Transaction in the Spot Market

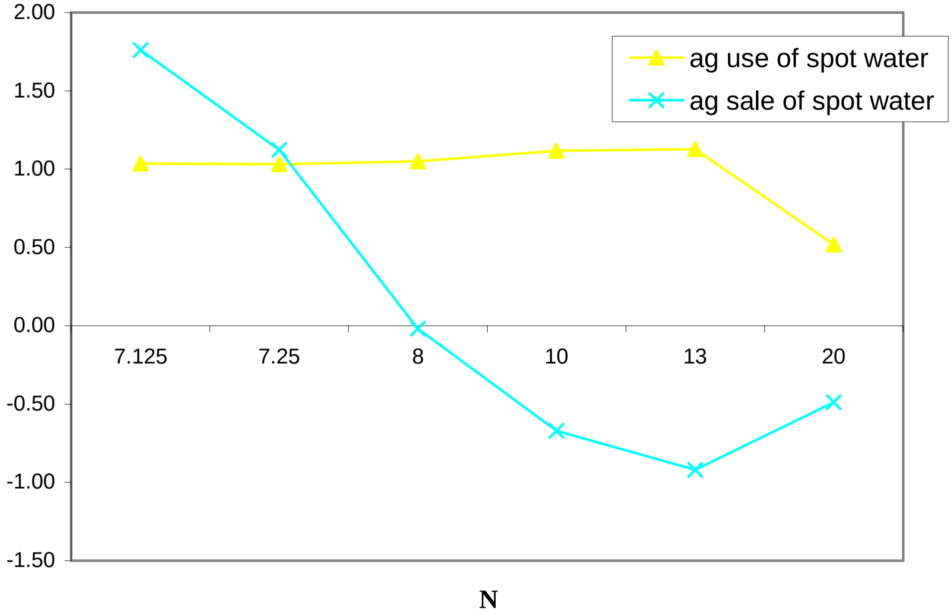


Figure 4: Effect of Share of Water in Ag Production (gamma) on n

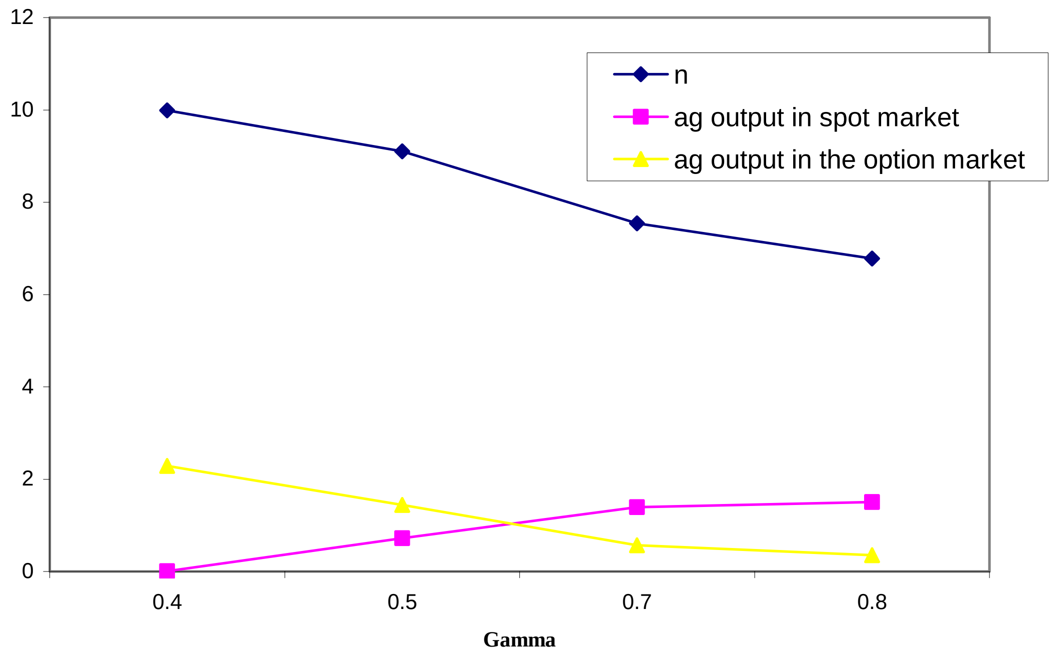


Figure 5: Effect of water share (gamma) in Ag Commodity Production

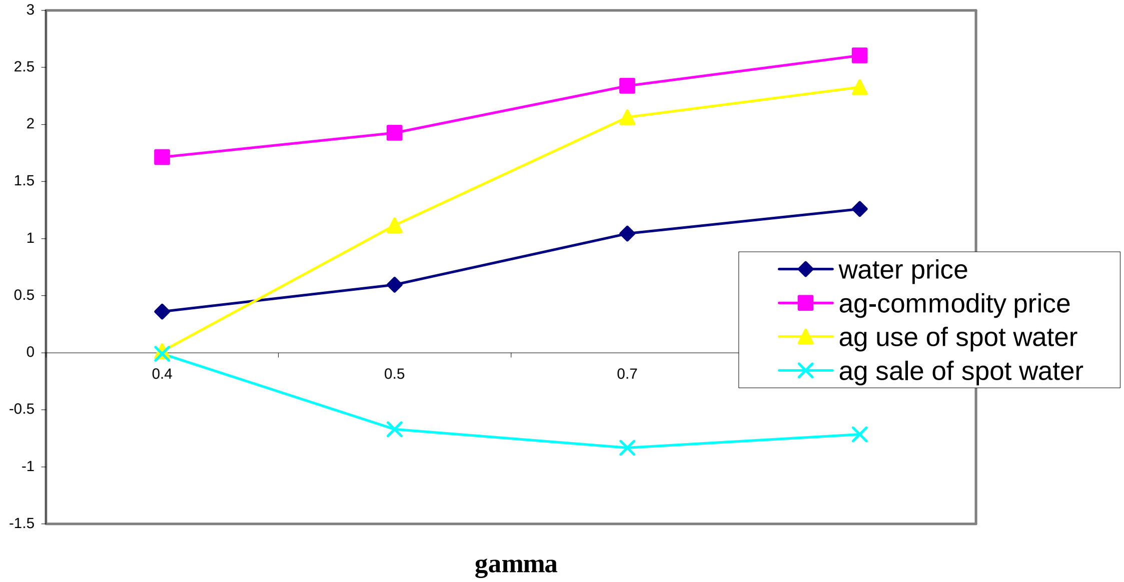


Figure 6: Effect of Elasticity of Ag-Commodity Demand (beta) on n

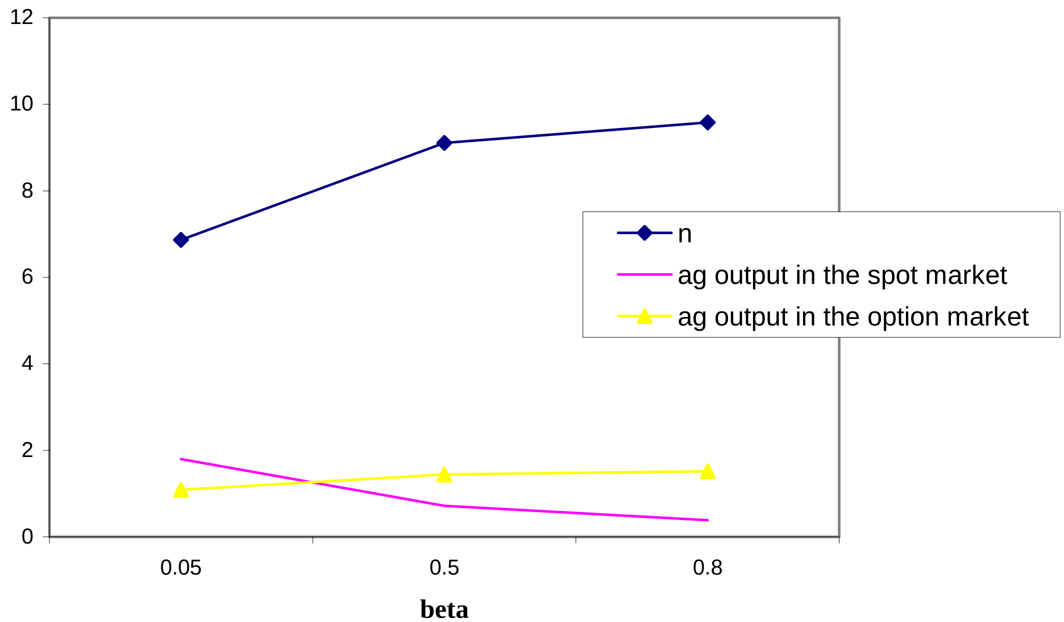


Figure 7: Effect of Elasticity of Ag Demand (beta) on Spot Market

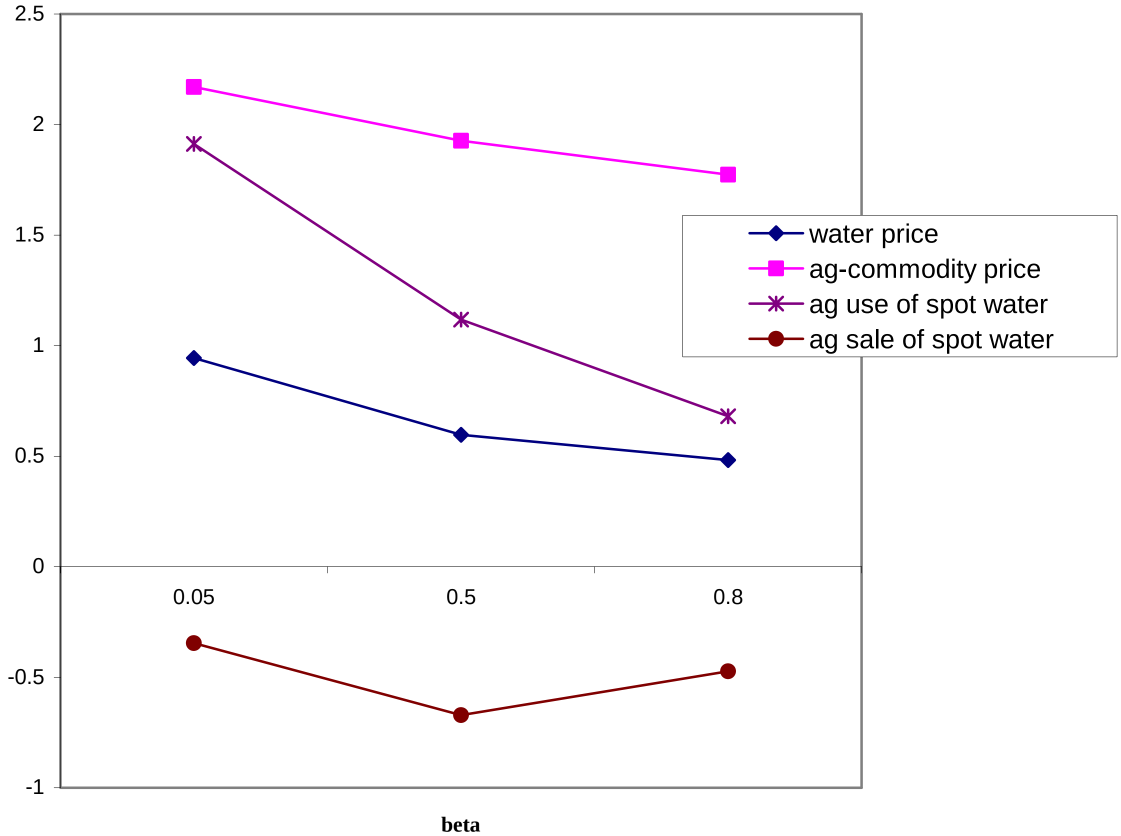


Figure 8: Effect of Land Availability on n

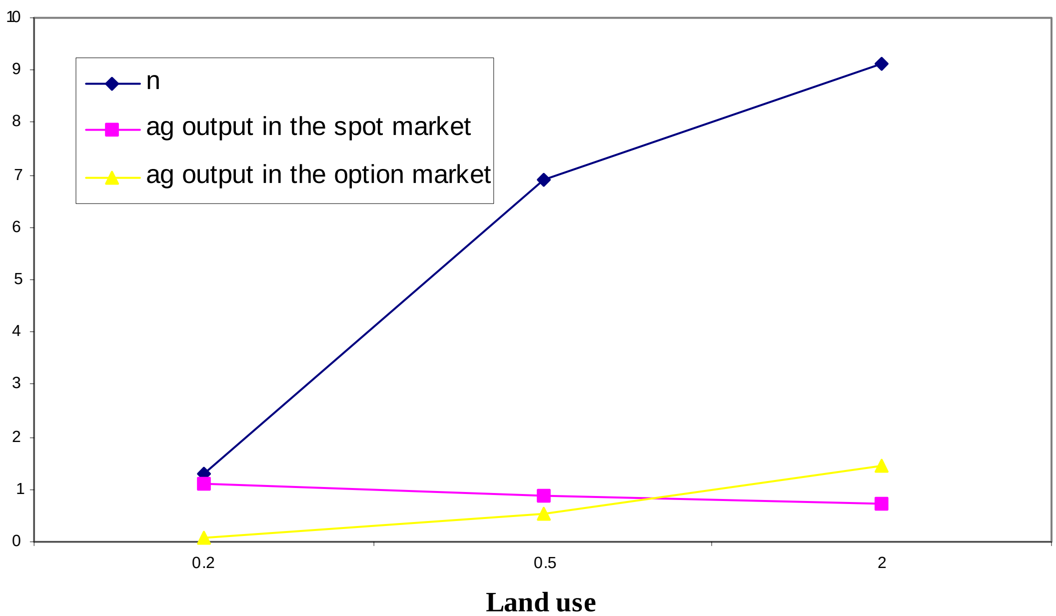


Figure 9: Effect of Land (L) on Spot Market

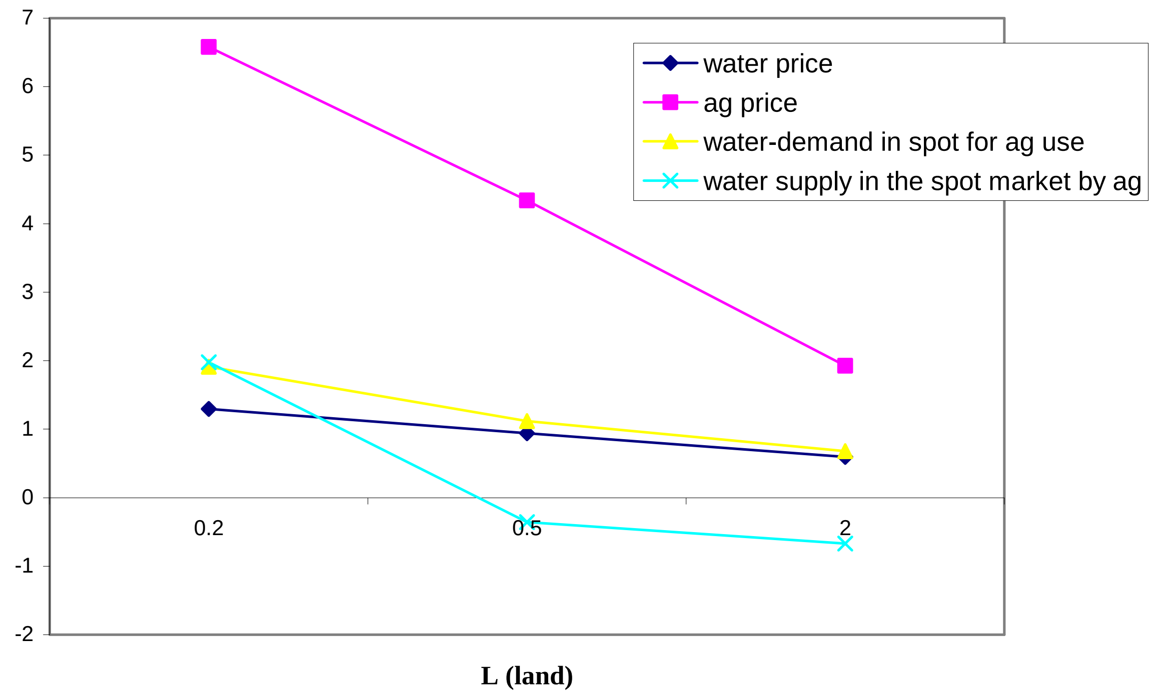


Figure 10: Effect of Ag Productivity Paramter (A) on n

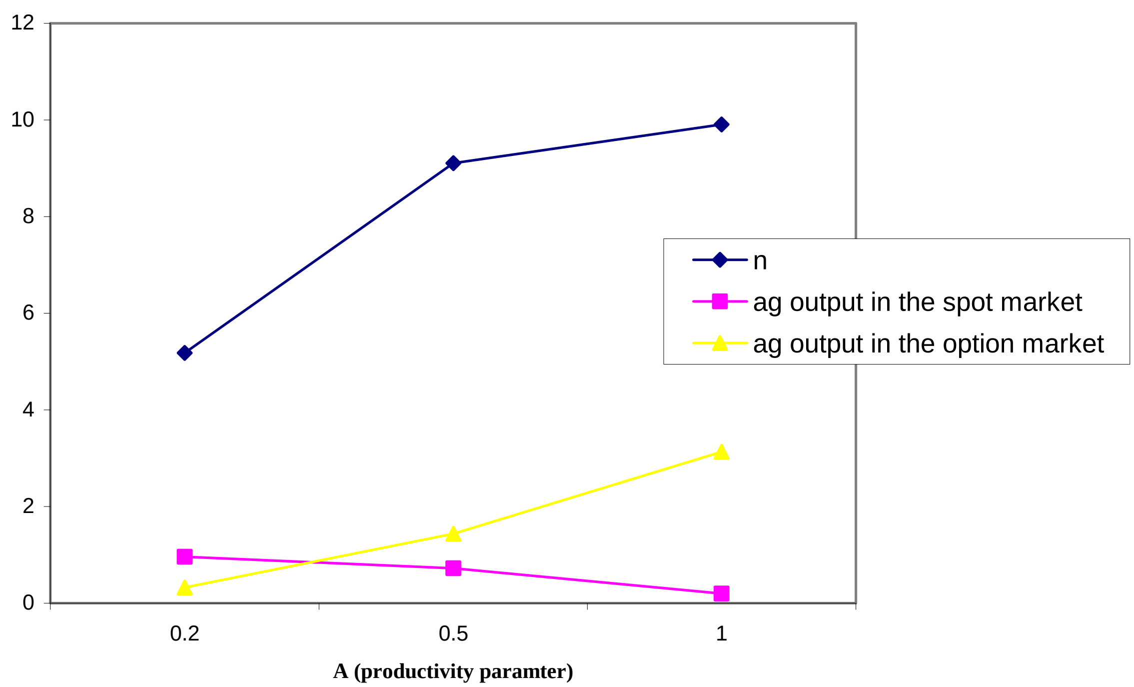
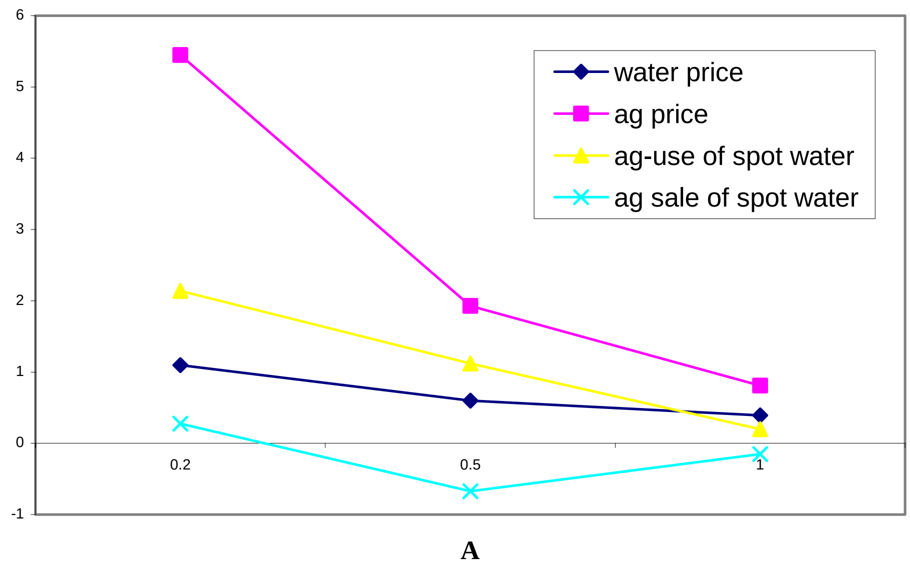


Figure 11: Effect of Ag Productivity Paramter A on spot Market



Results for the Two Farmer Model

Table1: Case of Spot Market Failure

Base Case	S (Farmer 2)	O (Farmer 2)
S (Farmer 1)	(-.59, -.57)	(-.55, .44)
O (Farmer 1)	(.21,-.32)	(.21, .44)

Table 2: Case of Option Market Failure

P0=3	S (Farmer 2)	O (Farmer 2)
S (Farmer 1)	(3.33, 5)	(4, .44)
O (Farmer 1)	(.21, 4.14)	(.21, .44)

Table 3: Possibility of Inferior Outcomes

k=.05, h=.005	S (Farmer 2)	O (Farmer 2)
S (Farmer 1)	**-0.5941 -0.5686**	**-0.5667 -0.6015**
O (Farmer 1)	**-0.8011 -0.4813**	**-0.5618 -0.3327**

Table 4: Higher Productivity Differential Impact (One Equilibrium)

k=.05, h=.005, A1=.1, A2=.6	S (Farmer 2)	O (Farmer 2)
S (Farmer 1)	**-0.619 -0.4891**	**-0.7062 0.1678**
O (Farmer 1)	**-0.9401 -0.218**	**-0.7862 0.3827**