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What Determines Farmers' Decision to Buy Irrigation Water in Water Abundant Regions? A Study of Groundwater Markets in Assam in Eastern India

by

Jitu Tamuli

(Tyagbir Hem Baruah College)

&

Mrinal Kanti Dutta

(Indian Institute of Technology Guwahati)

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Jitu Tamuli

Assistant Professor in Economics

Tyagbir Hem Baruah College, Jamugurihat, Assam, India

email:jitutamuli@gmail.com

Mrinal Kanti Dutta (Corresponding Author)

Professor in Economics, Dept. of Humanities and Social Sciences

Indian Institute of Technology Guwahati, India

Phone: +91-361-2582558 (O), +919954130771(Cell)

e-mail: mkdutta@iitg.ernet.in, mkdutta69@gmail.com

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Abstract:

Development of groundwater based irrigation technology has resulted in emergence of groundwater markets in many parts of India. Due to the localised nature of these markets, the decision to buy water by farmers is influenced not only by factors such as capital scarcity, size of operational holdings, number of fragmented plots, availability of institutional credit etc. but also by location of the site. The present study is carried out to unearth the factors influencing water buying decisions of farmers under groundwater market in water abundant regions of India taking the case of Assam in eastern India. Using field data from two districts of the state and with the help of logit regression analysis, the study examines the determinants of water buying decision of farmers. The results have shown that large own farm size, access to institutional credit, age and better contact with extension agencies significantly reduce the probability of water buying decision of a farmer. For a tenant farmer, the probability of buying water is found to be higher. The study notes that groundwater market in the study area resembles most of the characteristics of water markets reported by studies from the water scarce regions of Asian counties. The results, on the whole, indicate that water buying decision of a farmer in water abundant regions is the result of a combined effect of a number of socio-economic, farm specific and tube well specific factors.

Keywords: Groundwater market, Water selling, Water buying, Farm size, Logit regression, Assam

1. Introduction:

In a response to the development of groundwater based irrigation technology, there has been an emergence of institutions like groundwater markets (or water markets as it is popularly known) in some Asian countries like Pakistan, India, Bangladesh (Rinaudo and Stosser, 1997; Meinzen-Dick, 1998; Shah, 1991, 1993; Saleth, 1996, 1998), Indonesia, Jordan (Meinzen-Dick and Mendoza, 1996) and China (Zhang, 2006). Although the market can be both formal and informal, in Asian countries it is mostly considered to be an informal institutional arrangement where a farmer owning a tubewell sells the groundwater extracted from beneath his or her land to the willing buyers in the neighbourhood of the owner's plots without recourse to any legal sanction (Shah, 1991, 1993; Pant, 1992; Zhang, 2006). This groundwater market is usually considered as a 'residual market' as the sellers sell water only after meeting their own requirement (Shah 1993; Menizendick, 1998; Khair, 2012). Buyers in general, resort to water purchase when they are starved of capital to own a tubewell. Additionally, as noted by Pant (1992) buyers decide to purchase water when they perceive irrigation through purchase of ground water to be the most agreeable alternative in comparison to other sources of irrigation and they are able to physically gain access to the source of water. Many factors like the size of operational holdings, number of fragmented plots, farmers' access to institutional credit etc. enter into a farmer's decisions to water selling and water buying (Sharma and Sharma, 2006; Singh and Singh, 2006; Khair et al., 2012). However, the mode of operation of informal market which is influenced by many complexities like forms of water contract, bargaining power and other social factors also influences farmer's decision to buy water. Since, the groundwater market is localised and cannot be put under same footing; the differences in the factors affecting farmer participation in the market will be spatially different. In fact, water markets in India exhibit a wide variation in terms of organisational features and behavioural pattern in different regions (Saleth, 1998). However, proponents of groundwater markets have concurred that these differences are obvious as groundwater markets are village level localised institutions (Pant, 1991; Shah, 1993; Joshi, 2005, Zhang, 2006) and are highly dependent upon agro-climatic conditions, status of agricultural development, farming practices, levels of economic development and socio-economic conditions of the farmers. The essence of these studies is that there are differences in the issues of groundwater markets in water abundant regions compared to the water scarce regions. In the presence of such differences, Dubash (2000) notes that instead of looking at how the markets work or do not work, it is important to look at how and why they work differently in different locations, under different social and hydrological circumstances and with what effects. When the major focus of policy makers is the promotion of groundwater irrigation in water abundant region, rationing of water use in the market through energy policy doesn't seem relevant. While Palanisami and Easter (1991) argued for a strategy to encourage or legalise trading and increase competition either through community or private well development, Shah (1991) emphasised speeding up of the development of the market to saturate the available potential. In the similar fashion, Saleth (1994) noted that the issue in groundwater development in the Eastern part of India was the groundwater promotion rather than regulation and correction of institutional and technical bottlenecks for more development of groundwater for promotion of agriculture. Interestingly, while a number of studies on groundwater markets have come by now from the water scarce regions of the country, the number of studies from the water abundant regions of India like Assam is very limited.

In light of the above, the present study has been taken up to unearth the factors influencing water buying decisions of farmers under groundwater market in Assam, a water endowed state in eastern India. While examining the issue, the paper also looks into the operational features of groundwater market which might have a bearing on the decision of farmers to buy water.

Assam in the Eastern part of India has abundant groundwater reserves with heavy monsoon precipitation facilitating easy replenishment. The Central Groundwater Board (CGWB) of India has estimated the net availability of annual replenishable groundwater in the state at 24.89 bcm, out of which 22 percent are drafted for all purposes (industrial, domestic and agriculture) (Government of India, 2006). There has been a rapid growth of groundwater based minor irrigation scheme in the state in late nineties of the previous century as a part of public policy. Among the groundwater structures, shallow tubewells (STWs) have recorded phenomenal growth outstripping surface irrigation schemes (surface flow and surface lift) in the state. Significantly, these tubewells are installed under private and single ownership. As per the Minor Irrigation Census 2000-01 conducted by the Government of India, about 98 percent of the total STWs in Assam have been under individual ownership. The STW based irrigation has drawn huge response from the farmers. With this development some changes in cropping pattern of the state has also been noticed. As for example, there has been a gradual shift from autumn rice cultivation to summer rice (locally known as *boro* rice) cultivation in some districts of the state. Summer rice is a variety of rice in Assam which derives its name from the season in which it is harvested. In terms of acerage, it is relatively insignificant compared to winter rice and autumn rice. Summer rice in the state is normally sown in the dry months of December and January when there is hardly any rainfall, and as such it is almost impossible to raise the crop without irrigation. Most of the owners of the Water Extracting Mechanism (WEM) with excess capacity of their tubewells engage themselves in water transaction with the neighbouring farmers who do not own WEM (on their own) for market and non-market reasons (Dutta, 2011, 2012). This has resulted in the emergence of groundwater markets in some locations the state.

The rest of the paper is organised under five sections. Section 2 deals with the data source and type of data used in the study. While section 3 discusses the methods for examining the determinants of water buying, section 4 presents a discussion on the structure of the market. Section five includes a discussion of the factors affecting the water buying decision of farmers based on theoretical and empirical findings. The estimated results of the logit regression model are discussed in section six. Section seven provides a conclusion to the paper.

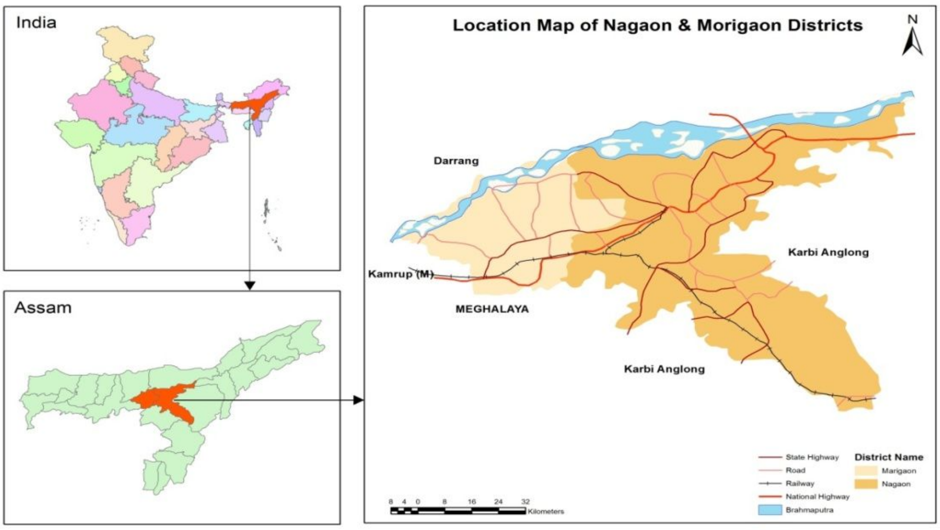
2. Data Source:

2.1 Study Area:

The study area has been chosen from those parts of the state where farmers cultivate summer rice purely based on groundwater irrigation and where farmers recourse to groundwater transaction. Accordingly, the study is carried out in the two districts of Nagaon and Morigaon in the Central Brahmaputra Valley Zone (CBVZ) of the state.

The locational maps of Nagaon and Morigaon districts in Assam are shown in figure 1. The upper portion of the figure shows the location of Assam in India and position of Nagaon and Morigaon districts within Assam. It also contains the map of the two districts together. The lower portion of the figure shows the position of the villages in the two districts where the field study was carried out.

The selection of the two districts is guided by the fact that the presence of groundwater markets is quite widespread in the low lying pockets of the two districts especially in the cultivation of summer rice. The field study is carried out following a multi-stage sampling procedure. In the first stage, the districts in which the study has been carried out are identified. Then for inclusion of farmers in the sample, the locations where the market has widespread presence are identified. In the next stage, a few villages from those locations are randomly selected and finally information on various issues of ground water market and agricultural practices are collected from a few randomly selected farm households from each of these villages. Since market practices are found to be similar in a particular village or in the same crop field, emphasis is not given on including a specific percentage of farmers from a particular village while selecting farm households. Emphasis is rather given on including farmers from a greater number of villages, so that spatial/regional variations on agricultural practices in the operation/functioning of groundwater markets can be captured.



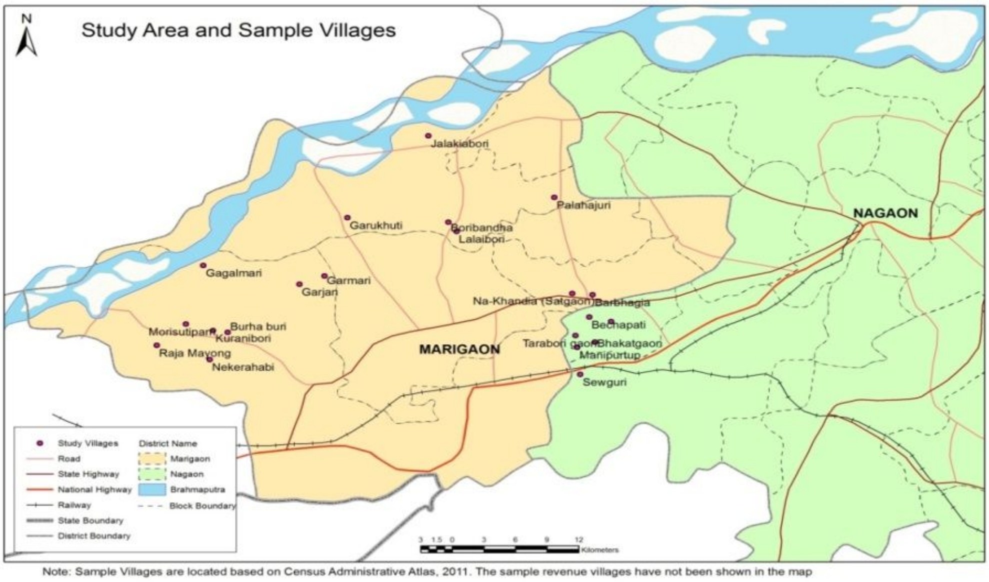


Fig. 1: Locational Map of the Study Area

2.2 Data Base and Sample:

The total number of farmers included in the sample is 198. As already mentioned, these farmers are engaged in the cultivation of summer rice with sole reliance on and virtually unrestricted access to groundwater. Summer rice is a variety of rice in Assam which derives its name from the season in which it is harvested. In terms of acerage, it is relatively insignificant compared to winter rice and autumn rice. It is normally sown in the dry months of December and January when there is hardly any rainfall, and as such it is almost impossible to raise the crop without irrigation. However, importance of this variety of rice has increased in recent years due to its higher yield and also due to the vagaries of nature to which winter rice is subjected. A specially structured and pre-tested questionnaire has been administered in the field to collect data during the agricultural year 2011-12. Data are collected mostly on farm and non-farm activities, demographic and locational characteristics. While the data on farm activities include number of irrigation, labour, wages, farm size, crop output and prices, capital assets, costs of cultivation, fertiliser application, etc., the data on the market related issues include the size of the market, mode of transaction, non-market factors and the issue of reliability.

3. Methods:

The structure and operational features of the market have been examined using simple descriptive statistics such as percentage, ratio, average etc. The determinants of the groundwater market, especially the determinants of the water buying decision have been examined using a logit regression model.

3.1 The Logit Regression Model for Examining Factors Influencing Water Buying Decision:

The decision to buy water of a farmer is a binary or dichotomous-response variable taking on the values "1" or "0". In such circumstances, in order to identify the factors and their relative role in influencing such dichotomous response variables in probabilistic sense, logit or probit model is used (Maddala, 1983; Gujarati and Sangeetha, 2007; Hill et al., 2011). However, there is little theoretical justification for choosing between probit and logit models as they often produce similar result (Greene, 2003). In a number of empirical studies on water markets, the logit model has usually been preferred to identify the factors determining tubewell ownership, water selling and water buying decisions of farmers. In this context, mention may be made of Saleth (1996) who has used a logitmodel to explain the determinants of the buying decision of water. Singh and Singh (2006), Sharma and Sharma (2006) and Khair et al. (2012) have applied logit regression models to identify the factors influencing both the buying and selling decisions of groundwater based on household level primary data. In this study, a logit model is used to identify the factors that influence farmers' decision to buy water. The model is formulated as follows.

The logit model postulates that P_i, the probability that i^{th} farmer buys groundwater, is a function of an index variable Z_i summarising a set of explanatory variablesX_{ki}. That is,

$$P_i = f(Z_i) = f(\alpha + \sum \beta_k X_{ki}) = \frac{1}{1+e^{-z_i}} = \frac{1}{1+e^{-\alpha + \sum \beta_k X_{ki}}} \text{--- } \mathbf{(1)}$$

Where,

Z_i =An underlying and unobserved index for the i^{th} farmer (when Z exceeds some threshold Z^*, the farmer is observed to be buyer; otherwise non-buyer).

X_{ki} = The k^{th} explanatory variable for the i^{th} farmer that may affect the farmer's decision to buy groundwater.

i=1, 2...N; where, N is the total number of sample farmers included in the study.

k= 1, 2 …M; where M is the total number of explanatory variables.

α = Constant

β = Vector of coefficients

e = Base of the natural logarithm and approximately equals to 2.718.

Now, Z_i is estimated as follows:

$$\log(\frac{P_i}{1-P_i}) = z_i = \alpha + \sum \beta_k X_{ki} \text{ --- (2)}$$

Thus, Z_i (in Equation 2), is a linear function of a host of explanatory variables. In fact Z_i is equal to the natural logarithm of the odd ratio, i.e. the ratio of probability that the farmer has purchased groundwater to the probability that the farmer has not.

The goodness of fit of the model has been checked using the Log-likelihood Ratio tests and a few pseudo coefficients of determination (pseudo R^2). In order to assess the effect of each selected explanatory variable on the probability of the water buying decision of a farmer, the marginal effects and elasticity coefficients are estimated. Marginal effects of the explanatory variables are the partial derivatives of probabilities with respect to the vector of explanatory variables and are computed at the mean of the explanatory variables. The value of the coefficient of marginal effects indicates the changes in decision of a farmer to buy water which is caused by a one unit change in the independent variable, *ceteris paribus*. The elasticity coefficient indicates that 1 percent change in the explanatory variable will change the probability of farmers' decision to buy water equal to the respective percentage of the elasticity coefficient (Khair et al. 2012).

4. Groundwater Market in the Study Area:

4.1 Market Arrangement:

There are six alternative market arrangements[1] in the field viz. Self-users (SU), Self-users + sellers (SU+S), Self-users+ sellers + buyers (SU+S+B), Self-users + buyers (SU+B), Buyers (B), and

[1]**Self-users+sellers**: Farmers with independent or joint ownership (or both) of tubewells, use water for cultivating their own plots as well as selling water to needy farmers in the vicinity of the tubewell, usually after meeting their own requirements.

Owners+sellers (OS). The distribution of the sample farmers under these six different structures of groundwater markets according to their size of operational holding is presented in Table 1.

Table 1, shown below, indicates that about 90.91percentof the sample farmers are engaged in water transactions while the rest (9.09%) are self-users. The "buyers" alone constitute the largest segment (39.90 percent) followed by "self-users+sellers" (38.38 percent), "self-users" (9.09 percent), "self-users+sellers+buyers" (7.07 percent), "owner+sellers" (3.54 percent) and "self-users + buyers" (2.02 percent). The majority of the sample buyers are found to be small (41.54 percent) and marginal farmers (56.82 percent). Buyers in the semi-medium category are only 5.13 percent. Distribution of the sample buyers according to the size of their operational holding explicitly shows that when the farm size increases, the number of buyers has decreased correspondingly. It supports the established theory of the market that buyers in the groundwater markets are usually small and marginal farmers. This finding is similar to the results of Fujita and Hossain (1995) in Bangladesh; Meinzen-Dick (1997) in Punjab province of Pakistan; Zhang et al. (2007) in China; Bhandari and Pandey (2006) in Nepal; and a couple of studies such as Deepak et al. (2005), Sharma and Sharma (2006), Khanna (2006), Singh and Singh (2006), Manjunatha et al. (2011a), Dutta (2012), Manonmani and Malathi (2012), etc. in India.

Buyers: The farmers who buy water from the nearest single or multiple tubewells usually adjacent to their agricultural plots. However, the possibility of water purchase from any distant source cannot be ruled out when there is suitable arrangement for water conveyance.
Self-users+sellers+buyers: The owner of tubewells who cultivate their agricultural plots with water from own tubewells, sell water to willing buyers after meeting their own requirement and buy water from other tubewells in another location, especially when their cultivable land is fragmented in two or more than two plots.
Self-users+buyers: the farmers with independent ownership or joint ownership of atubewell or tubewells use water from their own tubewells for own use in one plot and buy water from other tubewells in another plots.
Owner+sellers: refers to a situation in which some farmers have invested on tubewells, not to meet their own irrigation requirements, but for using it primarily for selling water to other farmers.
Self-users: Farmers with individual or joint ownership of tubewells and use it for cultivation on own plots

Table 1
Distribution of sample farmers according to the structure of groundwater market

Size class of operational holding (in hectare)	Category of participants in the water market						Total
	Self-users	Self-users +sellers	Self-users+ sellers + buyers	Self-users + buyers	Buyers	Owner +sellers	
Marginal (below 1)	5 (5.68%)	25 (28.41%)	2 (2.27%)	0	50 (56.82%)	6 (6.82%)	88 (100)
Small (1-2)	5 (7.69%)	25 (38.46%)	5 (7.69%)	2 (3.08%)	27 (41.54%)	1 (1.54%)	65 (100)
Semi-medium (2-4)	8 (20.51%)	22 (56.41%)	6 (15.38%)	1 (2.56%)	2 (5.13%)	0	39 (100)
Medium(4-10)	0	4 (66.67%)	1 (16.67%)	1 (16.67%)	0	0	6 (100)
Total	18 (9.09%)	76 (38.38%)	14 (7.07%)	4 (2.02%)	79 (39.90%)	7 (3.54%)	198 (100)

Note: Figures in parentheses indicate percentage of the row total.

In the case of sellers, out of the total sample "self-users+sellers", about 65.78 percent are small and marginal farmers. The number of "self-user+sellers" in semi-medium and medium categories of farm holdings constitute about 28.94 and 5.26 percent respectively. That the majority of the water sellers are concentrated in the category of small and marginal farmers, is in contrast with the established theory of the existing literature on groundwater markets which have reported that the water sellers are usually the large farmers whereas the buyers are small farmers (Saleth, 1998). The evidence of small and marginal farmers selling water has also been reported by studies like Dubash (2000) and Manjunatha et al. (2011a, 2011b) but the share of these farmers in the total water sellers has been not that high unlike one reported by this study. This study thus, marks a deviation from the established theory in the literature of water market that sellers are always the large scale farmers. Further, as clear from Table 1, a few members of the group "owners+sellers", though do not hold any cultivable land are in the possession of shallow tubewells and engage in water selling. This dimension of the market has even not been mentioned by Pant (1992) while explaining the conditions for the existence of groundwater markets. Thus, on the seller's side, it shows that the market has helped some of the tubewell owners to sell water not only in excess of their own use on self-operated area but also taking groundwater pumping as an additional source of income. It also suggests that the market is not residual to the buyers in all cases against the popular belief that groundwater market is residual.

4.2 Mode of Transaction and Water Charge:

There are three modes of payment of purchased groundwater: hourly rates, area based rate and volumetric rate. The earlier empirical studies have pointed out the dominance of hourly rate in water transaction (e.g., Pant, 1992; Janakarajan, 1993; Palmer-Jones, 1993; Satyasai, 1997; Shah and Ballabh, 1997; Hussain et al. 2005; Jha and Sinha, 2008; Khair et al., 2012, etc.). However, in the study area, water charges are based on an area approach. Under an area-based approach the amount of water charge is based on the amount of land irrigated. The general rule prevalent in the study area is that the expenses on fuel (diesel) are borne by the buyers themselves irrespective of the mode of payments especially when the water is bought from diesel operated pumpsets. The pattern of water charge realised in the study area is presented in Table 2. The information on water charge has been collected from both the buyers and sellers in the market to see the nature of transaction between different types of buyers and sellers.

Table 2
Nature of transaction cross different categories of market participants

Mode of transaction	Category of participants in groundwater market					
	Self-users + Sellers	Self-users + Sellers + Buyers	Owner + Sellers	Self-users + buyers	Buyers	Total
Cash	17	6	0	3	15	41 (22.77%)
Kind (with fixed charge)	51	5	3	1	59	119 (66.11%)
Kind (with output sharing)	5	2	3	0	0	10 (5.55%)
Cash and Kind (with fixed charge)	0	0	1	0	0	01 (0.55%)
Cash and Kind (with output sharing)	2	1	0	0	5	08 (4.44%)
Cash, Kind (with fixed charge) and Kind (with output sharing)	1	0	0	0	0	01 (0.55%)
Total	76	14	7	4	79	180 (100)

Notes: (a) Figures in parentheses indicate percentage of the column total.
(b) Self-users are excluded as they do not engage in water transaction.

The table shows that the mode of transaction in the market is found to be taking place in both cash and kind. The non-cash water charges are of two types: fixed charge and output sharing. The output sharing takes two forms, viz. output-sharing with or without cost sharing. However, the practice of non-cash transaction is found to be dominant in the study area (74.22 percent of the sample farmers have made the transaction in kind).Under kind based payment, about 66.49 percent of the total sample farmers are found to pay a fixed charge while 7.73 percent of the total sample farmers have made the payment on output sharing basis. The preference for kind-based payment is mainly for two reasons: *firstly*, buyers face difficulties in the beginning of the irrigation season to pay for water in cash when they also need to pay for fuel (in case of a diesel operated pumpsets), fertilisers, seedling and labour. *Secondly*, through this they can shift the burden of irrigation cost to the water sellers for about five to six months. Farmers in the study area have preferred output sharing as through this they may get partial or full concession at the time of payment when there is crop failure. The prevalent practice of water charges paid by the sample buyers under cash-based payment are presented in Table 3.Cash amounts are given in Indian Rupee (Rs.).

Table 3
Water charge under both of cash and non-cash transaction

Types of tubewell	**Amount per hectare (in Rs.) Cash**			**Amount per hectare (in quintal) Fixed-charged kind payment**		
	Minimum	**Maximum**	**Average**	**Minimum**	**Maximum**	**Average**
Diesel operated tubewell	2988.00	4482.00	3361.50*	05.98	11.95	07.41
Electricity operated tubewell	4482.00	5976.00	5695.87	08.96	17.93	13.66

*when operational cost of diesel tubewell is taken into account the water charge for a diesel operated tubewell will be Rs. 11,729/-

Table 3 shows that the average price charged for water per hectare of land, for the sample buyers participating in the groundwater markets is Rs. 3, 361.50 if water is bought from a diesel operated tubewell and Rs. 5, 695.87 if water is bought from an electric powered tubewell. The price varies from Rs. 2, 988.00 per hectare to Rs. 4, 482.00 per hectare when water is bought from diesel operated tubewell. It is also clear from table 3 that the average water charge, under the fixed charge in-kind payment system is 7.47 quintals per hectare, and 11.95 quintal/hectare respectively when water is bought from the diesel operated tubewell. The water charge under this mode of payment is almost double, that is 13.65 quintal per hectare, when the water is bought from the electric operated tubewells. In order to express the in-kind water charge in terms of monetary value, the total kind payment is multiplied by the prevalent average market price of the output (which is Rs. 712.50 per quintal). It has been found that the value of average water charge for electric tubewells is Rs. 9725.62/- which includes cost of water pumping. The total value of watercharge (water charge + operational cost) for diesel operated tubewells has been found to be Rs. 14,027.66/-. It clearly indicates that water charge for diesel operated tubewell is higher than the water charge for electric tubewells.

4.3 Interface of Groundwater Markets with other Non-market Factors:

4.3.1 Tenancy and Groundwater Market:

Groundwater markets are closely linked with other rural markets like informal credit markets and land tenancy markets (Meinzen-dick, 1992; Fujita and Hossain, 1995; Palmer-Jones, 1994; Saleth, 1998; Jacoby et al., 2004; Kajisa and Sakurai, 2003& 2005, etc.). The incidence of land tenancy among the sample water sellers and sample water buyers is shown in Table 4.

Table 4
Extent of tenancy among the participants of groundwater market

Types of participant	No. of tenants	Fixed rent/produce	Output sharing	Mortgage
Buyers	30 (31.95%)*	21 (70.00%)	8 (26.66 %)	1(3.33%)
Sellers	41 (42.27%)*	25 (60.98%)	16 (39.04%)	0
Total	71	46 (64.79%)	24 (33.80%)	1 (1.40%)

* Figures in parentheses indicate percentage of the total number in each category.
Rest of the figures in parentheses indicate percentage of the total number of tenants

It is evident from Table 4 that about 31.95 percent of the total water buyers have leased in land from the water sellers and about 42.27 percent of the total sellers have leased out land to the water buyers. The table also reveals that about 64.79 percent of the total cases of tenancy have taken the form of fixed charge whereas about 33.80 percent is based on output sharing.

4.3.2 Flexibility in Water Contract:

The functioning of the groundwater market is associated with a number of market imperfections. Palmer-Jones (1994), Meinzen-Dick (2000) and Dubash (2002) have outlined the complexity in the nature of water contracts which is mostly governed by the social processes. These lend the water sellers some market power to charge different prices to different buyers (Shah, 1993; Wood, 1995; Shah and Ballabh, 1997; Pant, 2004 & 2005; Jacoby et al., 2004). Though, the sample sellers in the present study are not found to have charged different water charges from different buyers, some of them have been found to have given concessions on water charges to some of their buyers. It has been found that about 25.57 percent of the sample water sellers have given concessions on water charges to their buyers. On enquiring who are the buyers enjoying these concessions, it has been found that about 56 percent of the sellers have given concessions to their brothers and the rest have given concessions to their relatives. This finding is akin to the results of Shah (1993) who found that transaction between water buying and water selling farm households were personal in a few cases. However, this is unlike Zhang (2006) who found the groundwater markets in Northern China to be almost fully impersonal. The extent of these price concessions in the study area vary from 10.00 percent (1.49 quintal per hectare) to 23.3 percent (5.97 quintal per hectare).

4.3.3 Other Services required to be rendered by the Buyers:

The nature and mode of operation of the village level groundwater market also shows that the price does not always guarantee access to water (Wood, 1995). In addition to water charge, some of the buyers are required to render some other services to the water sellers like operating the pump and irrigating the well owner's field (Janakarajan, 1993, 1994). In the present study too, about 35.05 percent of the buyers are found to provide some sort of free services to their respective water sellers in addition to the water charge paid. The different types of services provided by the buyers are listed in Table 5.

Table 5
Distribution of buyers providing services to the water sellers and types of these services

Types of other services	No. of buyers
Protecting and operating the pumpsets in the crop field	4 (11.76%)
Transporting the pumpsets to the field	7 (20.59%)
Any work asked by the water sellers & protecting the pumpsets in the field	3 (8.82%)
Any work asked by the water sellers	20 (58.82%)
Total	34 (100%)

Note: Figures in parentheses indicate the percentage of the column total.

It is evident from Table 5 that as high as 58.82 percent of buyers have to provide some sort of additional services demanded by the water sellers. About 20.59 percent of the sample buyers have to help the sellers in transporting the pumpset to and from the crop field. Another 11.76 percent have to render their services in operating and protecting the pumpset in the crop field. The buyers are required to provide these services in order to maintain a cordial relationship with the sellers, so that they are provided with timely supply of water at the time of requirement. A few sample buyers (8.82 percent) providing other services refused to render these free services but were denied water by the sellers leading to giving up of cultivation by the farmers. There is also evidence of preferential treatment of the buyers by the sellers as reported by Narayanamoorthy (1991). Normally, buyers who are siblings and close relatives of water sellers are given preference in providing water by the sellers. From this analysis, it may be concluded that market practices are not purely based on price for water. Instead, the water sellers exercise some monopoly power, though not reflected in the water charges, through some other means which are exogenous to the market system. A similar type of practice is reported by Ray (1998) in the operation of rural credit markets.

5. Factors Affecting Water Buying Decision:

The buyers of groundwater are primarily the farmers who do not own a tubewell but undertake cultivation of summer rice by purchasing water usually from the nearest owner-cum-water sellers though a few sellers are also found to be water buyers on fragmented plots. The sample farmers are categorised into two classes, viz., water buyers and non-buyers. Non-buyers include "self-users" and "self-users+sellers". Other categories of participants of water markets like "self-users+buyers" and "self-users+sellers+buyers" are excluded from the analysis to maintain mutual exclusiveness. Thus, as evident from Table 6 below, the total number of sample farmers considered for the analysis is 180. For the farmers who resort to water purchase, the dependent variable is assigned the value "1" and for the farmers who are non-buyers the value of the dependent variable is taken to be "0".

Table 6
Typology of sample farmers according to their decision to buy groundwater

Category of farmers	Decision to buy water		Total
	No	Yes	
Self-users	18	00	18 (10.00 %)
Self-users+sellers	76	00	76 (42.22%)
Buyers	00	79	79 (43.89%)
Owner+sellers	07	00	07 (3.89%)
Total	101	79	180 (100%)

Note: Figures in parentheses represent percentage of column total.

The available theoretical and empirical literature reflects on a number of factors that determine the water buying decision of a farmer. However, subject to the availability of data and their relevance in the context of the present study, a number of factors have been identified. The definition and descriptive statistics of the variables are presented in Table 7.Description of the variables and the nature of their likely impact (the expected sign of independent variables) on the probability of water purchase decision are given in appendix A.2.

Table 7
Definition and descriptive statistics of the variables included in the logit model

Variable	Definition	Minimum	Maximum	Mean	Std. Deviation
OFS	Own farm size (area in hectare)	0	12.04	1.34	1.51
TOHL	Total operational holding (area in hectare)	0	4.95	1.29	0.97
PAUB	Percentage of area under summer rice (in percent)	0	100.00	71.50	30.19
NFPT	Nos. of fragmented plots	1	5.00	1.52	0.75
DFNSI	Distance from the nearest source of irrigation (in meter)	20	700.00	155.84	96.97
AGE	Age of the head of the farm household (in years)	22	77.00	46.86	11.63

EDN	Education of the head of the farm household (in years)	0	15.00	5.39	4.95
SSI	Subsidiary source of income in the farm household (1 = Yes; 0, otherwise)				
ACIC	Access to institutional credit (1 = Yes; 0, otherwise)				
SCES	Score of the extensions services (in number)				
PSNR	Personal relation with buyers and sellers (1=yes, 2=No)				
CSTE	Caste of the farm household (1 = General caste; 0, otherwise)				
TNCY	Tenancy among the farmers (1 = if the farmer is tenant; 0 otherwise)				

6. Results and Discussion:

The results of the logit model used to identify factors influencing water buying decision in terms of MLE estimates, marginal effects and elasticity coefficients are presented in Table 8.

Table 8

Logit estimates for the likelihood of water buying decision of the sample farmers

Variables/Particulars	MLEs		Marginal effects		Elasticity
	Coefficient	Std. Error	dy/dx	Std. Err.	ey/ex
CONSTANT	3.1774**	1.4285			
OFS	-1.1502***	0.3494	-0.2675	0.0758	-0.9717
TOHL	0.2946	0.3652	0.0685	0.0842	0.2408
PAUB	0.0090	0.0075	0.0021	0.0017	0.4046
NFPT	0.2447	0.2739	0.0569	0.0639	0.2353
DFNSI	-0.0037*	0.0023	-0.0008	0.0005	-0.3598
AGE	-0.0401**	0.0192	-0.0093	0.0045	-1.1867
EDN	-0.0757	0.0483	-0.0176	0.0112	-0.2577
SSI	0.4416	0.4161	0.1028	0.0969	0.1289
ACIC	0.1854	0.4593	0.0435	0.1090	0.0331
SCES	-0.1854***	0.0702	-0.0431	0.0163	-0.3132
PSNR	-1.7627***	0.4716	-0.3722	0.0876	-0.4419
CSTE	-0.2063	0.4732	-0.0476	0.1085	-0.0503
TNCY	0.8748*	0.5046	0.2072	0.1201	0.1893
Log-likelihood of full model:					-83.946
Log-likelihood of null model					-126.657
LR Chi^2					85.423***
Over all pseudo R^2					0.337
Correct prediction (in percent)					72
Degrees of freedom					13
Total observation					180

Dependent variable: decision to buy water

*, ** and *** represent significance at 10percent, 5 percent and 1 percent levels respectively.

For a dummy variable, dy/dx is the discrete change of dummy from 0 to 1

It is clear from Table 8 that the model gives a good fit as the Likelihood Ratio Test (L-R Chi^2) is found to be highly significant. The Variance Inflation Factor (VIF) values used to check multi-collinearity problem, (shown in Table A.1 of Annexure-A.3) have shown absence of severe multi-collinearity problem in the model. The model has provided correct prediction to the extent of 72 percent of the dependent variable. The overall pseudo R^2 has turned out to be 0.337. Though a high value of pseudo R^2 is desirable, it is not always considered at par with the adjusted R^2 like in Ordinary Least Square (OLS). The significance of the explanatory variables, direction of change in dependent variable with respect to each explanatory variable, marginal effects and the elasticity coefficients are discussed below.

The coefficient of the variable "OFS" is found to be highly significant and negative, which implies that with increased own farm size, the probability of water buying decision of a farmer decreases. It also implies that when farmers' farm size increases, they wish to own a tubewell. Thus, it is appropriate that own farm size has a negative and significant influence on the decision to purchase water. The partial probability of own farm size is estimated to be (-) 0.267. It implies that other things remaining the same, one unit increase in own farm size of the farmer, will reduce the probability of water buying by 0.267 points. Similarly, the elasticity coefficient which is estimated to be (-) 0.97, implies that one percent increase in the "own farm size", leads to probability of water purchase to decrease by 97 percent, *ceteris paribus*.

The tenancy variable is statistically significant and its coefficient is found to be positive. It implies that if a farmer is a tenant he is more likely to be a buyer of water. Tenancy being a significant determinant of the water purchase decision, indicates the presence of a strong interlinkage between the operation of the water market and the land tenure system. The partial probability of tenancy is estimated to be 0.207. It implies that other things remaining the same, when a farmer becomes a tenant the probability of water buying increases by 0.207 points. Similarly, the elasticity coefficient which is estimated to be 0.18 implies that when the buyer turns out to be a tenant, the probability of water purchase will increase by 18 percent, *ceteris paribus*.

The coefficient of "DFNSI" is also found to be negative and significant. It indicates that when distance from the nearest source of irrigation/tubewell increases farmers are less likely to be buyers. The partial probability of the variable is found to be (-) 0.0008 which implies that when farmer's plots from the nearest source of irrigation increase by one meter, the likelihood of farmer's decision to buy water will decrease by 0.0008 points. The elasticity coefficient which is estimated to be (-) 0.35, implies that when distance of buyer's plots from the nearest source of tubewell increase by one percent, the probability of water purchase will decrease by 35 percent, *ceteris paribus*.

The coefficient on the “AGE” variable is found to be negative and significant. It implies that when the age of the farmer/farm household increases, it is more likely that he does not buy water. When experience increases the farmer may find it better to own WED than buying water as water purchase is also beset with the question of reliability. The partial probability value of (-) 0.009 of the variable indicates that when age of the farmer/farm household increases by one year, the probability of farmer’s decision to buy water will decrease by 0.009 points. The elasticity coefficient which is estimated to be (-) 1.18, implies that one percent increase in age of the farmer the probability of water purchase will decrease by 118 percent, *ceteris paribus*.

The available literature on water market reports that the operation of water markets is influenced by the presence of personal relationship between buyers and sellers apart from the market factors. In the present study, the coefficient of the variable “PSNR” as a determinant of water buying decision has come out as significant but negative. It implies that the personal relationship of a farmer with the water seller does not encourage him/her to buy water. The result seems to be counter intuitive as the buyers having a personal relationship with the seller enjoy concession at the time of payment of water charges (discussed in section 4.3.2) and as such personal relationship with the potential water sellers may induce him/her to buy water. However, looking at the issue from the sellers’ point of view, it is observed that a seller is usually not much interested to sell water to those farmers with whom he has personal relationship. The reason being the fact that these farmers (buyers) claim concession in the water rate and they are also found to be the highest defaulters in the payment of water charge. Since sellers refuse to sell water under these circumstances, the buyers in spite of having personal relationship with the seller may not be interested to buy water. The elasticity coefficient of the variable implies that *ceteris paribus,* when a buyer has a personal relationship with the seller, the probability of water buying decision goes down by 44 percent.

The coefficient of “SCES” is found to be negative and highly significant. It indicates that when a farmer receives more extension services in the form of information on farming technology etc. the farmer is more likely to own a tubewell rather than resorting to water purchase. The partial probability of access to extension services is found to be (-) 0.043. This implies that *ceteris paribus*, one point increase in scores of extension services will decrease the probability of water buying by 0.043 points. Similarly, the elasticity coefficient which is estimated to be 0.31 implies that one percent increase in the scores of extension services obtained by the farmer will increase the probability of water purchase by 31 percent, *ceteris paribus*.

The variable "NFT" though not significant the sign of it has been found to be positive as expected.

7. Conclusion:

It is clear from the above discussion that groundwater market in the water abundant state of Assam displays some characteristics which are in contrast to the ones found in water scarce regions. Out of the six alternative forms of market arrangement for groundwater, about 5.88 percent of the sample tubewell owners have been found possessing tubewells only for selling groundwater. Thus, on the seller's side, it shows that the market has helped some of the tubewell owners to sell water not only in excess of their own use on self-operated area but also taking groundwater pumping as an additional source of income. It also suggests that the market is not residual to all buyers discarding the established theory that the "water market is residual". This aspect of the water market was not considered by Pant (1992) also while discussing the conditions for the existence of the market. Thus, the present study suggests the need for revisiting the conditions for existence of water markets particularly in water abundant regions. The prevalent water charge is found to be almost uniform within a village and across villages except a few. It makes the market more competitive despite the presence of some monopoly elements on the part of the tubewell owner-cum-sellers. It also supports the anticipation of prominent researchers (Shah, 1993; Saleth, 1998) that with abundance in groundwater availability, the market would become more competitive.

The results of the logit analysis on the determinants of buying water have shown that own farm size, distance of buyers' plots from the nearest source of irrigation, education and age of the farmer have exerted significant influence on water purchase decision of the farmers. The positive role of education on the probability of water purchase has also been identified by Singh and Singh (2003) and Khair et al (2011). The negative impact of farm size on the probability of water purchase and positive role of fragmentation of land holding have also been identified by Singh and Singh (2003), Sharma and Sharma (2006). Thus, regarding determinants of water buying decision, the study validates some of the major findings of earlier studies. The fact that tenants are mostly water buyers prominently displays that the market is intertwined with the land tenancy. The study notes that farmers' better contact with the extension services reduces the probability of a farmer's water buying decision indicating that government's support in farming helps farmers to gain more control of irrigation water. The discussion on the determinants of water buying decision indicates that the water buying decision of farmers in ground water markets is a combined effect of a number of farm specific, farmer specific and non-market factors.

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Appendix:

A.1: Empirical model for determinants of water buying decision:

Incorporating the explanatory variables shown in Table 7, the functional form of the model specified in Equation-1 can be formulated for estimating the parameters affecting buying decision of the relevant sample farmers in the following manner.

$\log\left(\frac{P_i}{1-P_i}\right) = z_i$, Where P_i= Probability of buying water.

$$\mathbf{Z_i = \alpha + \beta_1(OFS) + \beta_2(TOHL) + \beta_3(PAUB) + \beta_4(ACIC) + \beta_5(SSI) + \beta_6(AGE) + \beta_7(EDN) + \beta_8(NFPT) + \beta_9(CSTE) + \beta_{10}(DFNSI) + \beta_{11}(SCES) + \beta_{12}(PSNR) + \beta_{13}(TNCY) + U_i}$$

U_i is the error term.

A.2 The description of the variables:

Own Farm Size (OFS): Own farm size, measured in hectare, is the total cultivated area owned by the water buyer. This is an important determinant of farmer's decision to sell or buy groundwater. Existing literature points out that: (a) OFS of a farmer is inversely related to the probability of buying water.

***Size of Operational Holdings**(TOHL)*:In most instances though own farm size of a farmer is low, if the farmer has the scope to lease in land usually attached to his own plot, the farmer may choose to own a tubewell. The size of total operational holdings measured in hectare is important to consider as a factor that influences water purchase decision of a farmer. Thus, larger is the size of operational holdings lower may be the possibility to buy water.

Percentage of Area under Summer Rice** (PAUB):** In corollary to the size of operational holding, the percentage of total operational holdings brought under summer rice cultivation, in the present study, is also an important factor that largely affects water purchase decision of a sample farmer. In the context of present study, it is assumed that when percentage of area under summer rice cultivation increases the farmer is more inclined to owning a tubewell. Thus, this variable has a negative impact on water purchase.

Fragmentation of Land Holdings *(FPLT)****:*** The fragmentation of land has been captured as the number of fragmented plots where summer rice is cultivated. When farmers' cultivable plots are dispersed in many plots, it is quite unlikely that with single water extracting device a farmer will be able to irrigate all his land. Besides, moving pumps around frequently may also cause early break-down which may entail more cost. Therefore, when degree of fragmentation is high and fragmented plots are smaller in size: a farmer may not own a pumpset or a farmer with pumpset may not be willing to own more than one pumpset rather he may prefer to buy water on fragmented plots.

Subsidiary Occupation (SSI)*:* Since, a farm family with stable subsidiary source of income may have higher capacity to invest in pumpsets, a farmer with subsidiary sources of income may own tubewell and may not be engaged in water purchase. However, such a farmer might have less concentration on farming and might not invest heavily in agriculture. The income from the subsidiary sources may also not be sufficient to own a tubewell. Therefore, a farmer with subsidiary source of income may or may not turn out to be an owner. Therefore, the probable effect of this variable on water buying decision is not conclusive. The role of this variable on the probability of buying water is captured by constructing a dummy variable whether the farmer family has subsidiary income sources or not. Value "1" is assigned for having subsidiary source of income in the family, "0" otherwise.

Education (EDN):It is measured by the number of formal years of schooling completed by a farmer. It is a proxy variable for know-how of information regarding improved farm practices, managerial skills, etc. which are important for effective farming. Since, education reflects possible effect of human capital (Bhandari and Pandey, 2006) and managerial ability (Singh and Singh, 2006), it may enhance farmer's understanding to own a tubewell to ensure assured irrigation. A owner of a tubewell is less likely to buy water. Thus, higher level of education of a farmer may increase his probability to own a tubewell resulting in lower probability of water purchase.

Age (AGE):Age of the water sellers is measured in terms of years. It is a proxy for experience of farmer in farming that helps in effective farming. With experience farmers may be tempted to own a tubewell to ensure adequate irrigation water in the field. In the present case, summer rice is a water intensive crop and is based primarily on groundwater irrigation. Besides, an experienced farmer may also take an initiative to own a WED jointly in order to minimise its own share in initial investment required to buy a pumpset.

Access to Institutional Credit (ATIC):Installation of a tubewell requires a large initial investment in the form of buying the pumpset, equipments and installation of the boring which a financially capable and large farmer only is capable of doing through own savings. But most of the poor farmers cannot afford to install a WED in particular and purchase other agricultural inputs in general. The provision of formal credit may enable farmers to own a WED. Thus, access to credit from formal sources is expected to affect ownership of tubewell of the farmer and is negatively related to the water buying decision of a farmer. The impact of the variable is captured by constructing a dummy variable. The variable assumes the value “1” if the farm household has an access to institutional credit and “0” otherwise.

Distance of Buyers’ Plots from the Nearest Tubewell (DFNSI):Distance of the sample buyers’ plots from the nearest WED is measured in terms of meter. It has been found that farmers generally do not prefer buying water from distant sources of tubewell which is constrained by non-availability of conveyance facilities. Thus the a priori assumption is that nearer the source of irrigation water, greater is the possibility that a farmer buys water.

Access to Extension Services (ACES):Nine questions related to farmers’ interaction with government extension agency have been included in the schedule. Farmers’ responses to these queries were codified into scores. The total scores on these queries could vary from 0 to 9 depending on the level of the farmers' interaction with the extension agencies. A farmer's scores on these questions have been used as the measure of his access to extension service. Thus, a higher score of extension service implies that the farmer has better contact with the extension agencies and is deriving benefits of the services. A farmer benefited by better extension services is expected to have availed facilities under different schemes enabling the farmer to own a tubewell.

***Caste (CSTE)*:**A few available literatures also conclude that ownership of tubewell is skewed towards upper caste. It is expected that farmer belonging to upper caste may have better access to financial resources and thus be able to own a tubewell. However, in the field, no such division like upper and lower caste is observed. Rather, caste as a variable is captured in the field either as general caste or other backward caste or scheduled caste or scheduled tribe. Since presence of inequalities among the farmers by their caste cannot be ruled out, this variable is included in the study to check whether there is any difference in the probability of buying water based on caste. The possible effect of this variable can be captured as a dummy assigning the value "1" if the farmer belongs to the general category, "0", otherwise.

Personal Relationship (PSNR): Some of the buyers and sellers in water market are found to have personal relationship with each other. Thus, the role of kinship in influencing water purchase decision cannot be ruled out. As found in the study, one of the reasons for buying water is that the buyers enjoy some concession when they have kinship relationship with the seller. On the other hand, from the point of view of the seller, granting concession for water purchase may not be the best feasible option. Rather, he might expect the buyers to render some other services over and above the payment of water charge, an act which may not be possible in case of buyers having personal relationship with the sellers. Thus, the likely impact of this variable on the water purchase decision is not very clear. The variable is captured by a dummy taking on the value "1" if the buyer has a personal relationship with the seller and "0" otherwise.

Tenancy (TNCY):Tenancy as a variable (denoted in short as *TNCY*) influencing water purchase decision assumes significance in the present study. Tenancy is intertwined with the operation of water market. Therefore, it is assumed that a buyer who is also a tenant of the water seller, is more likely to enter into water buying contract with the seller. This variable is captured by a dummy taking on the value "1" if the farmer is a tenant and "0" otherwise.

Appendix A.3: Collinearity diagnostics for independent variables influencing water buying decisions of a farmer

Table A.1

Collinearity diagnostics for independent variables influencing water buying decision

Variables	VIF*	SRT VIF	Tolerance	R^2
OFS	1.71	1.31	0.58	0.42
TOHL	1.49	1.22	0.67	0.33
PAUB	1.28	1.13	0.78	0.22
NFPT	1.04	1.02	0.97	0.03
DFNSI	1.16	1.08	0.86	0.14
AGE	1.28	1.13	0.78	0.22

EDN	1.41	1.19	0.71	0.29
SSI	1.14	1.07	0.87	0.13
ACIC	1.13	1.06	0.89	0.11
SCES	1.17	1.08	0.85	0.15
PSNR	1.40	1.19	0.71	0.29
CSTE	1.35	1.16	0.74	0.26
TNCY	1.25	1.12	0.80	0.20
Mean VIF	**1.29**			

Note: There are many recommendations for acceptable levels of VIF. While the most commonly suggested maximum level of VIF is 10 (Kennedy, 1992), a recommended maximum VIF value of 5 and even 4 have also been found in the literature. Considering the most commonly used VIF value of 10, the presence of collinearity in preferred model has been checked.