Determinants of water purchases by pistachio producers in an informal groundwater market: a case study from Iran

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Abstract

Market-based water allocation systems have the potential to ensure that scarce water will flow to the user who earns the highest marginal value from that water. However, the number of recorded instances where water supply problems are solved by market-based systems remains limited. This study attempts to identify the decisive factors that motivate farmers’ participation in informal spot water markets in the Rafsanjan aquifer in south-eastern Iran. A two-stage random sampling was carried out in a field survey from November 2008 to February 2009. A logit model is used to test the factors affecting farmers’ decisions to buy groundwater from neighbours who share the same pump. The results show that the technological variables contribute substantially to the participation decision. For example, a decrease in water quality, an increase in the age of the garden, and an increase in the size of the water quota reduce the probability of participation. In contrast, more scattered plots, a higher water flow level from pumping, and a deeper well increase the probability of participation in water markets. Finally, the results suggest that in this area, the participation in water markets is motivated more by profit increasing factors than by farmer socioeconomic characteristics.

Keywords: Groundwater; Informal spot water market; Logit; Participation; Pistachio; Rafsanjan; Water quality

1. Introduction

Water markets are an economic instrument to allocate scarce water resources in an efficient way, particularly for agricultural uses (Tsur, 2005). A water market can be defined as a set of institutional arrangements that permit water entitlements (for abstraction and use) to be traded (Theesfeld, 2010). Water markets exist in different forms throughout the world. They may be formal or informal, organised or spontaneous. Their participants may trade water rights (e.g., the right to purchase a quantity of water at a particular price during specific periods of time), or they may trade water at the spot price or for

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future delivery (Tsur & Dinar, 1997). The exact conditions for trading water market items vary substantially between countries so that a number of different terminologies exist. If entitlements for water are the object of the trade, then the literature refers to markets for water rights or water licences. If long-term access to water is traded, the common term is leasing. If just the allocation of water is traded, then in Australia, the term water allocation is used, while in Canada water assignment seems more common. Short-term trades of water allocation are also referred to as spot markets and this is the terminology which is adequate for our case (Brewer et al., 2008; Giannoccaro et al., 2013). Water markets can generate substantial gains for buyers and sellers that would not otherwise occur, and these gains increase as water availability declines (Grafton et al., 2011). Moreover, trading water in annual spot markets can reduce farmers’ economic vulnerability caused by water supply variability across irrigation seasons (Calatrava & Garrido, 2005). Formal water markets with different mechanisms (such as water bank, spot water market, bulletin board markets, double action markets, derivative markets or environmental leasing purchase program) are mainly employed in developed countries chiefly in the western United States and Australia. In developing countries, the formal water market is limited to Chile (up to our knowledge) but informal groundwater markets proliferate throughout Asia (Hadjigeorgalis, 2008). Well designed market based instruments (MBIs) for managing natural resources generally and water resources specifically, can yield substantial economic and environmental benefits (Whitten et al., 2007)1. Removing barriers to water trade and creation of an efficient water market is one of the main initiatives in water reform in Australia which is implemented in the Murray-Darling Basin (Connell & Grafton, 2011)2. For a water market to be successful, there needs to be heterogeneity among potential water users (Schoengold & Zilberman, 2007). Additionally, a skewed distribution of pumping rights which includes one big user and a moderate number of smaller ones is often helpful for establishing a successful groundwater market (Garrido & Livingston, 2003). Water markets are not free of criticisms. Confusion and resentment are reported at the initial stages of water reform and water market creation because of the volatile nature of deregulation (Kiem, 2013). Water markets have the potential to cope with climate change but the effect is not certain (Wei et al., 2011; Kiem, 2013). The water market can have negative effects on the existence of rural communities by encouraging many to leave the sector (Kiem, 2013). One of the possible externalities of expansion of the water market is the reduction of in-stream flow which affects the environment or downstream users (Hadjigeorgalis, 2008; Hung et al., 2014). Involving environment in the water market is a remedy to the problem by the buyback of entitlements for supporting the environment as done by the Australian government in 2007 (Connell & Grafton, 2011). Hung et al. (2014) have promoted the idea of ‘locational water rights’ to deal with unidirectional downstream flow of the river to deal with environmental and downstream externalities. Groundwater markets have positive equity, efficiency and sustainability impacts in favourable hydro-geological conditions. However, this may not necessarily be true for the areas with groundwater depletion threat (Mukherji, 2007). Therefore, water markets should be judged not only on economic efficiency grounds but also on equity or environmental sustainability grounds, at least in contexts where these aims are deemed to be important (Grafton et al., 2011). The market friction mechanism is one of the MBIs for managing natural resources and socioeconomic information on

1 Whitten et al. (2007) have presented a policy framework analysis for design and implementation of MBIs.
2 The development of water markets in MDB is under analysis by researchers regularly and their studies are accessible here: http://www.mdba.gov.au/what-we-do/basin-plan.
heterogeneity of resource holders is crucial for any policy design (Whitten et al., 2007). Determinants of irrigators’ participation in the water market form some of the necessary information.

Governments and water authorities that are interested in establishing water markets as a tool to reallocate water away from inefficient uses and towards more valuable applications should learn more about the factors influencing irrigators’ decisions to participate in water trading (Wheeler et al., 2009). As there are few transactions among water users (Young, 1986; Donohew, 2009), analysing available water markets and their participants would be particularly useful for policy makers who may need to alter existing institutions, so that the costs of water trade do not outweigh the potential gains from trade. The results of participatory studies are also of interest to farmers and municipal water providers that are actively engaged in developing water-leasing alternatives (Pritchett et al., 2008). An improved understanding of the functioning of existing formal or informal water markets can provide lessons for the institutional design of a water market, and in particular shed light on the question of why the same rules might be successful in one water market but may not be as successful in another market (Grafton et al., 2011).

In spite of many legal barriers in front of the water market in Iran, an informal spot water market can be found in Rafsanjan aquifer in the south-eastern part of the country. As a result of the heterogeneous ownership pattern of land and groundwater use, water scarcity, and high-priced pistachio production in this region, a limited informal water market exists among pistachio producers who share the same pumps in this region. As water market development is on the agenda as a tool for water resources management in Iran, analysing this limited water market as a case study can provide important lessons to policy makers even beyond the region of Rafsanjan. As mentioned by Hadjigeorgalis (2008), strengthening the institutional capacities of informal water markets in developing countries is an effective approach to support the water market. In this paper we make use of a comprehensive dataset on irrigation water use for pistachio production in Rafsanjan which allows us to shed light on the factors affecting the decision of farmers to participate in the informal water markets. We focus on the demand side of the water markets, i.e., participating farmers are those who bought groundwater for irrigation of pistachio orchards during the 2007–2008 agricultural year in the Rafsanjan aquifer region. The logit model is used for the analysis of the participation decision. This study contributes to the on-going debate over the expansion of the groundwater market by utilising a unique dataset which allows us to consider area-specific factors such as water quality and farm structure. The results suggest that technological factors and environmental factors are more important than farmers’ socioeconomic characteristics in the participation decision.

The paper is structured as follows. In the next section, the existing literature on water market participation is reviewed, and crucial factors for the participation decision are derived. The specific water right and water market regulations in the study region are discussed in section 3 in order to describe the legal and economic framework under which the informal water market has developed. Subsequently, in section 4, the methodology, data and study area are presented. Section 5 shows the results of the econometric estimation of the participation model. Finally, section 6 presents the discussion and conclusion.

2. Previous studies on water market participation

Generally, the literature on performance of different aspects of the water market is increasing. However, the existing literature on the determinants of participation in the water market is relatively scarce.
In particular in the context of developing countries and groundwater markets, data issues are a major challenge. Documentation of market transactions and of participants’ characteristics is often difficult. The few existing empirical studies either analyse the real participation in the water markets, or focus on the willingness to become active in water markets, i.e., on hypothetical participation. Some existing studies are reviewed below.

Meinzen-Dick (1996) produced one of the first studies on participation in the groundwater market. She used the International Food Policy Research Institute (IFPRI) 1991/1992 micro-survey data in Pakistan to identify the factors that predict who purchased tubewell water during two seasons. Size of landownership and the age of household head had a significant negative effect on water purchase. She hypothesised that the location of fields relative to canals and tubewells is likely to have an effect on water purchase decisions along with the groundwater quality but as the data were not available, these factors are not modelled. She concluded that promoting private groundwater markets can improve equity by spreading available water to as many farmers as possible. Moreover, directing credit and technical assistance for tubewell installation toward medium size farms will foster the development of groundwater markets and improve the equity of access to valuable groundwater resources.

Sharma & Sharma (2006) studied the factors influencing farmers’ decisions to buy groundwater resources for irrigation in Rajasthan, India. Significant factors were: size of land holding, negatively; land fragmentation, positively; higher capacity of water lifting device, negatively; and education, positively. Non-significant factors which affected the model positively were: family workers per ha, proportion of high-valued crops and proportion of joint-installed wells. They concluded that this water market, which was based on an undefined property rights system, failed to bring social equity as water sellers were charging exorbitant prices to poor, small-scale and marginal farmers. They advised state intervention to regulate the water markets.

Wheeler et al. (2009) investigated whether the early adoption of water trading was associated with the same factors that influenced the adoption of agricultural innovations in general. The data came from water trading during 1998–1999 within the Goulburn-Murray Irrigation District in Australia. The logit model and multinomial logit were used to compare the factors affecting decisions to buy, sell, or not trade. Results showed that irrigators were more likely to participate in allocation trading if they: were older; lived in the region; had a farm business plan; had a higher total water entitlement; irrigated more hectares of land; were newer to farming; had a higher percentage of total irrigated crop land; were female; had education beyond the level of Year 10; had a higher farm operational surplus; believed their farm had low productivity; had a lower percentage of irrigated areas for cattle than for cropland; and did not agree that irrigators should provide water for the environment. They concluded that water trading did conform to many expectations held about the adoption of agricultural innovations. They found only limited evidence to support the market efficiency hypothesis that water moved from lower value uses to higher value uses. In contrast to the early stages of water trade, Wheeler et al. (2010) showed that in the mature stages of water trade overall participation in the water entitlement market is driven mainly by farm level factors rather than farmer socioeconomic characteristics. This reflects the long- and short-term nature of the two markets.

A group of studies has focused on the willingness to participate in water markets and on the willingness to sell irrigation water. Pritchett et al. (2008) studied the factors affecting the willingness to lease, rather than permanently transfer, irrigation water to municipal areas of the South Platte Basin in Colorado, USA. Statistically significant variables that had a negative impact on willingness to lease were: debt ratio, which may indicate a more urgent need to sell water rights; percentage of water supply from groundwater, high levels of which preclude one from leasing water; and proximity...
to urban centres, which implies increased pressure for urban development and thus increased likelihood of selling of water rights. Statistically significant variables that had a positive effect on willingness to lease were: quantity of acres under irrigation, which may indicate a large quantity of water available for lease; concern for rural communities; and willingness to work with municipalities and other organisations, which is necessary to establish a lease agreement.

The decision of the Australian government in 2007–2008 to buy water for environmental restoration was the motivation for Wheeler et al. (2012) to analyse the factors affecting the farmers’ willingness to sell water to the Australian government for environmental restoration. Attitudinal factors seem to influence future willingness to sell more than actual sales. Some of the farm and financial related factors such as ownership of water entitlements and farm debt are positively associated with water sale behaviour, but they have influenced actual sales of water more than future willingness to sell water. Increases in future water prices will encourage future water offers. The history of each irrigation region’s water allocation, past experience with droughts, institutional policy issues, regional factors, and the different trends in major commodity prices additionally influence irrigators’ decisions and willingness to sell irrigation water.

Giannoccaro et al. (2013) have used a semi-quantitative method and focus group discussions to study the stakeholders’ perceptions of preferences for and attitudes towards water markets in Guadalquivir River Basin in Spain. They compared different stakeholder groups (managers vs. farmers; water right holders vs. non-holders) statistically with the information acquired through a survey which consisted of 12 statements. The results showed that respondents have a positive perception of water markets. The water right holders were found not to be interested in selling their water rights permanently in contrast to the non-holders who were keen on the permanent purchase of water rights.

Cook & Rabotyagov (2014) employed both an experimental design and a mail survey to test the preferences for leasing irrigation water by senior water right holders in the upper area of Yakima River Basin in Washington State in the USA. The results of a random-parameter logit model based on 49 participants in the experiments indicated that they were more likely to accept a lease if they were in the last year of their timothy hay stand, had an associate’s degree level of education, understood the risk aversion experiment, and currently grew timothy hay on farms. On the other hand, the results based on the mail survey (119 irrigator responses) showed that for the 1-year full-season water lease contract, older irrigators required a higher premium and irrigators with higher levels of education required lower premiums. Those with college or associate’s degree required higher premiums to accept a 5-year lease, while those with a long family history of land ownership required lower premiums for water market contracts. The authors concluded that irrigators prefer to lease to other irrigators more than other types of buyers and that they prefer split-season to full-season leases.

Giannoccaro et al. (2015) focused on the influence of drought on farmers’ willingness to trade and the potential for intra-basin trading in the Guadalquivir and the Almanzora River Basins in Spain. The results of the survey showed that the farmers have different views toward the intra-basin and inter-basin water trade in the two study areas. In Guadalquivir Basin, more farmers would sell than buy water allocation in a normal year, while the reverse is true for drought years. Drought conditions led to an increase in the number of farmers who were willing to buy water, but this positive effect on willingness to pay (WTP) of the participants is not significant. On the contrary, the difference between normal and drought years is not found in the Almanzora Basin for participation in the market, but farmers there were more willing to trade (buy and sell). However, farmers were willing to pay significantly more for the water under drought conditions. The results showed that a certain volumetric threshold must be reached before non-irrigators would enter the market and the willingness to participate in
water markets was higher for those with prior knowledge on the water market. Finally, the survey results showed that scope for irrigation water reallocation by markets was limited and many respondents did not find the water market ethical.

One important lesson emerges from the existing literature. In the majority of the studies presented above, socioeconomic characteristics are found to be important. Technological factors are also important and we especially recognise them for water market participation. In this study we consider environmental variables, technological variables and socioeconomic characteristics of farmers. These variables are selected by analysing former studies and recognising the influential variables which have been considered before. As water quality is a neglected factor in the available literature, it is considered in this study as a major contribution to this research area. Spatial aspects is an additional issue which is tested for in this study.

3. Water rights and water market in Iran

In Iran, the law of Fair Distribution of Water (1983)3 shapes the institutions governing water use. Under this law, people receive the legal permission to use groundwater, which legally is viewed as being in public ownership, for specific intended water uses. These permissions constitute a form of private property rights. The Ministry of Energy (MOE) is responsible for issuing new permissions for applicants by considering the hydro-geological condition of the aquifer (this permission is named entitlement in this text later on). The MOE can stop issuing new entitlements for depleted aquifers. It is not foreseen in the ‘Law of Fair Distribution of Water’ that the MOE can cancel an issued entitlement. Applicants for new entitlements under this law can base their application on either historical water use or on a business plan for new activities. However, the selection process of eligible applicants is not transparent. The entitlements can be expected to have relatively high shadow values, depending on the water charge level of the wells and the water quality. At the moment, the agricultural wells are in general not equipped with smart meters. However, the MOE has the right to control the discharge level of the wells in order to stop overexploitation. The MOE can oblige the entitlement holder to employ a smart meter. There are some restrictions in this law which limit the scope for trading these entitlements in water markets: for instance, paragraph 27 announces that the water entitlement is limited to the land or the uses which are prescribed in the specific entitlement. The usage can be changed when the government makes other decisions in that region. Additionally, paragraph 28 prohibits any use of the water entitlements different from the given permission. Moreover, the transfer of the entitlements for agricultural use should be done under the monitoring of the MOE with the transmission of the land to the new user by keeping the same permitted usages.

Although the law of Fair Distribution of Water does not support water trade in a practical way, water markets have been considered by the Iranian government as a possible pathway toward more efficient uses of scarce water resources in recent years. There have been a number of formal attempts to implement water policies which utilise water markets as an instrument in water resources management. According to the second amendment of article 106 of the Iran Third Five Year Development Plan (2000)4 the government is obliged to support the introduction of local water markets in order to improve conservation and management of scarce water resources. In

\[3\] Majlis of Iran (1983), Act No 22/17335.
\[4\] Majlis of Iran (2000), Act No Gh-3705.
another attempt, the government has approved the ‘Sectoral Water Resources Management Decree’ (2005). In part J of this cabinet decree, the government has considered water market formation and water right strengthening as an important action for country level water resources management. In 2007, a new department called the Office of Regulation and Market Development of Water and Electricity was established within the MOE whose intended main task was to regulate water markets. To the authors’ knowledge, this task has not yet been accomplished. As the functioning of a water market critically depends on the availability of clearly specified water rights (Holden & Thobani, 1996), yet another institutional change has been put forward through article 141 of the Iran Fifth Five Year Development Plan (2011). According to this article, the government is obliged to issue controlled tradable certificates for the all historical water right owners and users until the beginning of 2016. Although these activities by legislators and government have tried to support and to encourage the expansion of water markets during recent years, real improvements in the establishment and functioning of water markets as an economic instrument in water resources management have been limited at best (ISNA News Agency, 2012; IRNA News Agency, 2014; Ministry of Energy News Agency, 2015). Therefore, the actually observed water trade in the study region should be viewed in the context of a more informal water market.

4. Methodology

4.1. Study area and survey

From November 2008 to February 2009, a field survey was conducted in Rafsanjan County in the south-eastern part of Iran. The main reason for selecting Rafsanjan was its unique agricultural production pattern and its size. Table 1 shows some general characteristics of the Rafsanjan aquifer. As Table 1 shows, there are more than 1,300 active deep wells in the Rafsanjan plain, and most of them provide irrigation water for pistachio orchards while very few are used for other activities (WRS (2014), form code: 420-042). The general hydrograph of Rafsanjan shows an annual drop of 64 cm on average. Moreover, the intensive use of groundwater has affected the aquifer’s water quality and has increased the water salinity. The pumps are working 24 hours per day throughout the year even in winter. They stop pumping only when blackouts happen (for electric pumps) or when it rains (as irrigation is not possible in field capacity (FC) condition of the soil). The latest data show that the 20 years average annual rainfall in Rafsanjan is 78.5 mm (mainly in winter). In the study years, the annual rainfall was 44 mm in 2007 and 57.1 mm in 2008. However, the pumping pattern was not affected by the missing precipitation.

5 Cabinet of Iran (2005), Bill No H248T/29098.
7 Majlis of Iran (2011), Act No 419/73285.
9 The monthly precipitation and temperature data for the period 1993–2014 are accessible in the Appendix (available with the online version of this paper).
According to the Food and Agriculture Organization of the United Nations (FAO) database (FAOSTAT for 2011), Iran, with 258,000 hectares of pistachio orchards, has the world’s largest plantation area, followed by the USA with 62,000 hectares. American pistachio producers, with access to more sophisticated agricultural technology, are however much more productive than their Iranian counterparts. Good-quality pistachios are a very special kind of nut and they require very hot summers and very cold winters, which are the normal weather conditions in Rafsanjan. Increasing salinity can reduce pistachio harvest quantity and quality, however due to the pistachio’s salinity resistance there would be no significant reduction of crop production up to 8,000 μS/cm (Iran Pistachio Association, 2011). Rafsanjan is the biggest pistachio-producing area in Iran and the whole area has become specialised in pistachio production during recent years. Excluding saffron, pistachio is the most expensive agricultural crop in Iran, and Iranian pistachio production is an export-oriented industry.

The spot water market of the Rafsanjan aquifer is not fully formally defined as the water rights and entitlements lack a clear definition. It can be categorised as an informal water market. Within the Rafsanjan aquifer, some farmers sell their extra water requirements from the same well or neighbouring wells to other neighbours after meeting their own water requirements. The buyers and sellers are established farmers and irrigators with their established water entitlements. New permits for new wells will not be issued as the Rafsanjan aquifer is considered by the MOE as depleted. According to Goldhamer (2005), the range between FC and permanent wilting point per hectare is wide for pistachios. Therefore, the amount of water to be consumed depends on the farm management. In this study, we recognise that there is a huge variation in the water quota defined per hectare in our sample (Max: 22,779 m³, Min: 2,463 m³).

Data were gathered using two-stage random sampling. Considering the different water quality found within the study area, and the high cost of water quality studies, a readily available 4-year dataset from the Rafsanjan Irrigation Water Authority (RIWA) was used for the first-stage sample selection. The

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10 The average pistachio production per hectare for Iran was 1.1 ton and for the USA was 3.3 ton during 2002–2011.
RIWA randomly samples 60 agricultural wells within the aquifer, and checks chemical and water parameters such as electrical conductivity (EC), pH, etc., seasonally in order to observe any quality changes that may occur.

The two surveys comprised two different questionnaires: one concerning wells (first-stage random sampling) and the other concerning households (second-stage random sampling). The questionnaire concerning wells was designed after consultations with irrigators, pumpers and well representatives and it captures information on well ownership, various technical aspects, historical trends in water use, well management, labour force, energy consumption, maintenance, water charge and property value. The household questionnaire collects information on garden management and garden structure, the value of harvested crops, household socioeconomic structure, inputs, garden operational costs, processing costs, water provision costs and water trade. Also included within the questionnaires were questions asking for agricultural expenditures over a 1-year period, and crop yield levels and product sale prices for a 2-year period. As the sample of wells was random, it includes both large- and small-scale farmers11.

In the first stage of the sampling framework, we contacted the wells’ representatives, and used the well-specific survey instrument in face-to-face interviews with the well managers. For the second stage of the survey, the wells’ representatives provided a list of the farmers who were using the same well. From this list, the farmers were randomly selected and interviewed (face-to-face, using the farmer-specific questionnaire). In order to accommodate the skewed distributions in farm sizes around some wells, we ensured in such cases that at least one of the larger farmers was included in the sample. The ownership pattern is very diverse. There were cases where two or three wells belonged to one landlord or where one well was owned by 200 people. From the list of 60 agricultural wells from RIWA, four well representatives did not cooperate during the survey. Of the remaining 56 wells, some jointly irrigated a specific area and some had additional neighbouring wells from which pumped water was used to irrigate a specific area. Finally the representatives of the 52 pumping units were interviewed, along with more than 157 farmers whose land is dispersed around the aquifer. Each pumping unit refers to the number of wells which irrigate a specific farm area. There could be one well or many. Usually, a pumping unit has a common management pattern for all wells inside that pumping unit. All pumped water from the available wells inside a pumping unit is mixed for irrigation. The survey covers only those farms which are irrigated by those specific pumping units. Many farmers owned other big or small pieces of properties here and there but they were not focus of this survey as the sampling is based on the pumps.

Figure 1 shows the position of target wells in the study area (the latitude and longitude data of well geographical locations were gathered during the survey). As Figure 1 shows, this aquifer is divided into three parts which are connected at the bottom, but the hydro-geological characters differ slightly between the parts. A total of 44% of the deep wells are in southern part of the aquifer, 31% are in the western and north-western part, and 25% are in the eastern and north-eastern part (RIWA). This fact was considered for sample selection and field survey.

As a result of heterogeneous water-land ownership of the area, the spot water market is not recognised by all 52 pumping units. We found that water markets were operating among those pumping units with many owners, rather than those with few owners. Table 2 shows the number of farms and wells which are considered in the analysis. Importantly, only four farms are using modern drip irrigation whilst the others still apply traditional furrow irrigation systems.

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11 The two questionnaires can be provided upon request.
Figure 2 shows the histograms of EC and pH as water quality variables. As Figure 2 shows, intensive use of groundwater has decreased the water quality around Rafsanjan aquifer. Nevertheless, different water quality can be recognised around the aquifer. We have distinguished between water...
quota (defined as the farm’s theoretical maximum share of well water based on pumping for 365 days per year), and actual water use. Furthermore, we have distinguished between the volume of the water transferred to the farm from other wells or transferred to other farms, and traded water.

In water market analysis, three different possible groups should be distinguished: water buyers, water sellers and those who both buy and sell. In well-established water markets, we can even consider non-trading water users as a separate category. In this study we focus only on buyers and their characteristics, whom we compared with non-buyers in order to obtain a mutually exclusive sample. Hours of water pumping is the common unit of water trading among neighbours. When the buyer and seller reach a

Table 2. Pumping unit and farm participation in water market.

<table>
<thead>
<tr>
<th></th>
<th>Number of pumping units</th>
<th>Number of farms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total number in sample observations</td>
<td>52</td>
<td>157</td>
</tr>
<tr>
<td>Availability of spot water market</td>
<td>41</td>
<td>145</td>
</tr>
<tr>
<td>Active participation in spot market</td>
<td>–</td>
<td>28</td>
</tr>
</tbody>
</table>

Source: own calculations.

Fig. 2. Irrigation water quality at water pumping units.

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compromise, they have to arrange the delivery with the well representative or a technical observer of the well. Afterwards, the number of traded hours of well water is delivered to the buyer from the pump. It must be considered that the traded water is a commodity that cannot be transported easily, and most of the time trade is only possible for neighbouring farmers. The pattern of wells’ water distribution can encourage or discourage spot water market expansion.

4.2. Model specification

As the dependent variable in this study (participation in the water market) is a binary variable (0 or 1), so a binary response model is required. We employ the logit model from the family of generalised linear models (GLMs) which models the response probability \( Pr(Y) \) conditional on a set of variables \( X \) as follows:

\[
Pr(Y = 1|X) = F(X, \beta) = F(\beta X) \tag{1}
\]

\[
Pr(Y = 0|X) = 1 - F(X, \beta) = 1 - F(\beta X) \tag{2}
\]

where \( Y \) is the dependent binary variable exhibiting two possibilities: farmers who bought water from the spot water market \( (Y = 1) \) and farmers who did not buy water \( (Y = 0) \). The vector of explanatory variable \( X \) denotes the full set of independent variables. These variables cover both technological aspects of farm and water pumps, and household characteristics. \( \beta \) is the set of parameters to be estimated that reflects the impacts of marginal changes in \( X \) on the probability of participation. The function \( F(.) \) takes on values strictly between zero and one \((0 < F(.) < 1)\), and could be any cumulative distribution function. Equation (1) shows the probability of the farmer participating in a spot water market and Equation (2) shows the probability that the farmer does not try to buy water from a spot water market. In the logit model, \( F(.) \) is the logistic function and can be written as follows:

\[
F(\beta X) = \frac{exp(\beta X)}{1 + exp(\beta X)} \tag{3}
\]

which is between zero and one for all real numbers (Wooldridge, 2004, ch. 17.1)

During the interviews, a substantial reluctance against questions about sales of water was clearly visible. Farmers were much more willing to answer the questions about buying water than about selling water. This observed pattern is most likely connected to the legal constraints surrounding water trading in the Iranian water law. This law is non-transparent on water selling possibility. This could be one reason for reluctance on answering the water selling questions. Therefore, we can focus only on an analysis of the factors which are affecting water buying. The variables included in \( X \) were selected by considering technological aspects of the farms, socioeconomic characteristics of the farmers, and quality-quantity aspects of water. As mentioned previously (see section 2), most of the other studies have suffered when finding the determinants of the water buying decision due to data shortages or the specific water market setting. The selection and testing of the influential factors inside the logit

\[^{13}\text{The deviance, also called the log likelihood (ratio) statistic, is used to assess the goodness of fit of the model (Dobson, 2001).}\]
model in this study are based on the importance of these factors in the study region (e.g. pistachio orchards’ structure), the data shortages mentioned in the former studies (e.g. spatial aspects of farms), or both of the above mentioned issues (e.g. water quality). Another criterion for selecting the variables was the general approach in participatory literatures for selection of socioeconomic variables. In order to select the most suitable model, a General-to-Specific approach is applied. Table 3 shows a summary of variables used in the establishment of the model.

5. Results

5.1. The role of water market in the study area

Water trade covers a small share of water use per hectare among farmers in the sample. Figure 3 shows two histograms displaying the volume of traded water as a percentage of total water use, and a plot chart showing the relationship between farm size and the share of bought water as a percentage of total water use. Table 4 and Table 5 categorise the participants in the water market according to land ownership and water quota.

Table 4 shows that the smallholders with small farm size (less than 5 ha) cover the major part of the sample, and also the major participants in the water market. It seems that very large farms are less constrained by their allocated water entitlement since they do not buy any irrigation water.

Table 5 shows that by considering the sample size and water ownership structure of the sample, farmers with less water quota defined per ha (less than 5,000 m³/ha) and farmers with water quota of 15,000–20,000 m³/ha are the major participants in the water market. It is remarkable that one of the active

<table>
<thead>
<tr>
<th>Participation in water market (dummy as dependent variable)</th>
<th>Means</th>
<th>SD</th>
<th>Max</th>
<th>Min</th>
</tr>
</thead>
<tbody>
<tr>
<td>Using other wells (dummy)</td>
<td>0.16</td>
<td>0.37</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Having other jobs (dummy)</td>
<td>0.31</td>
<td>0.49</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>No. of fragmented plots</td>
<td>3.43</td>
<td>2.57</td>
<td>15</td>
<td>1</td>
</tr>
<tr>
<td>Average age of trees in garden</td>
<td>25.13</td>
<td>8.83</td>
<td>65</td>
<td>4.67</td>
</tr>
<tr>
<td>Insurance cost (1,000 Rial)</td>
<td>2125.52</td>
<td>9010.74</td>
<td>100,000</td>
<td>0</td>
</tr>
<tr>
<td>Pistachio production (ton) per ha</td>
<td>1.31</td>
<td>0.69</td>
<td>3.45</td>
<td>0</td>
</tr>
<tr>
<td>Water quota per ha (cubic metre)</td>
<td>9902.04</td>
<td>4483.32</td>
<td>22,776</td>
<td>2463.75</td>
</tr>
<tr>
<td>Depth of water level (metre)</td>
<td>63.05</td>
<td>30.5</td>
<td>123.47</td>
<td>8.11</td>
</tr>
<tr>
<td>Share of labour costs from all variable costs</td>
<td>45.9</td>
<td>11.76</td>
<td>79.63</td>
<td>17.37</td>
</tr>
<tr>
<td>EC (μS/cm)</td>
<td>6364.04</td>
<td>3753.68</td>
<td>17,400</td>
<td>1,314</td>
</tr>
<tr>
<td>pH</td>
<td>7.58</td>
<td>0.39</td>
<td>8.6</td>
<td>6.7</td>
</tr>
</tbody>
</table>

Source: own calculations.

14 Some of the potential variables are tested but they are not significant in the model. The most important non-significant factors are presented as follows: farm size, pumping costs, household size, farmer literacy level, the share of pesticide costs, manure and fertiliser costs, machine costs from total variable costs, number of male trees, etc.
participants in the water market comes from the group of farmers with a relatively high water quota. Soil quality and the initial decision of devoting a higher water quota to those areas can be one reason for this phenomenon. Therefore, this group of farmers are still seeking extra water to apply more irrigation. However, the general trend shows that participation rate reduces when water quota per hectare increases.

Table 4. Land ownership status of study participants in spot water market.

<table>
<thead>
<tr>
<th>Area of land owned (ha)</th>
<th>Participants (buyers)</th>
<th>Non-participants</th>
<th>Number of observations</th>
</tr>
</thead>
<tbody>
<tr>
<td>0–5</td>
<td>23</td>
<td>97</td>
<td>120</td>
</tr>
<tr>
<td>5–10</td>
<td>0</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>10–15</td>
<td>3</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>15–20</td>
<td>1</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>20–25</td>
<td>1</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>&gt;25</td>
<td>0</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Sum</td>
<td>28</td>
<td>117</td>
<td>145</td>
</tr>
</tbody>
</table>

Source: own calculations.

Fig. 3. Relative shares of bought water as a percentage of water quota, and water used related to farm size.
Nevertheless, Figure 3 shows that traded water is not huge compared to the water quota for the participants. However, smaller farms seem to buy a higher share of water than the large farms.

5.2. Results of econometric model

Table 6 shows the results of the logit regression. This model is tested for multicollinearity and heteroscedasticity. As the coefficients in the logit model do not reflect the marginal effects of the explanatory factors affecting the decision to buy groundwater and calculated probabilities of factors affecting the outcome (per cent).

<table>
<thead>
<tr>
<th></th>
<th>Estimate</th>
<th>Marginal effect (unit: per cent)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Intercept)</td>
<td>18.12 (7.55)*</td>
<td>–</td>
</tr>
<tr>
<td>Using other wells (dummy)</td>
<td>2.08 (0.76)**</td>
<td>30.95 (14.69)*</td>
</tr>
<tr>
<td>Having other jobs (dummy)</td>
<td>1.18 (0.56)*</td>
<td>11.78 (6.39)</td>
</tr>
<tr>
<td>No. of fragmented plots</td>
<td>0.29 (0.11)**</td>
<td>2.56 (0.92)**</td>
</tr>
<tr>
<td>Average age of trees in garden</td>
<td>−0.08 (0.03)*</td>
<td>−0.67 (0.314)*</td>
</tr>
<tr>
<td>Insurance cost (1,000 Rial)</td>
<td>0.000004 (0.00003)</td>
<td>0.0003 (0.0002)</td>
</tr>
<tr>
<td>Pistachio production (ton) per ha</td>
<td>1.07 (0.4)**</td>
<td>9.3 (3.7)*</td>
</tr>
<tr>
<td>Water quota per ha (1,000 cubic metre)</td>
<td>−0.15 (0.07)*</td>
<td>−1.3 (0.6)*</td>
</tr>
<tr>
<td>Depth of water level (meter)</td>
<td>0.04 (0.01)**</td>
<td>0.31 (0.094)**</td>
</tr>
<tr>
<td>Share of labour costs from all variable costs</td>
<td>−0.06 (0.03)*</td>
<td>−0.49 (0.227)*</td>
</tr>
<tr>
<td>pH</td>
<td>−2.40 (0.95)*</td>
<td>−20.93 (8.46)*</td>
</tr>
<tr>
<td>EC (dS/m)</td>
<td>−0.26 (0.11)*</td>
<td>−2.25 (0.89)*</td>
</tr>
<tr>
<td>Null deviance</td>
<td>142.301</td>
<td>df: 144</td>
</tr>
<tr>
<td>Residual deviance</td>
<td>98.122</td>
<td>df: 133</td>
</tr>
<tr>
<td>AIC</td>
<td>122.12</td>
<td></td>
</tr>
<tr>
<td>Model test:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Difference of deviance</td>
<td>44.179</td>
<td></td>
</tr>
<tr>
<td>Difference of df</td>
<td>11</td>
<td></td>
</tr>
<tr>
<td>Model P-value</td>
<td>&lt;0.0001</td>
<td></td>
</tr>
<tr>
<td>Wald statistic</td>
<td>40.3</td>
<td></td>
</tr>
</tbody>
</table>

Note: estimate of the coefficients are given with standard errors in the parentheses.
Level of significance: *P-value <0.05; **P-value <0.01.
Source: own calculations.
variables on the probability of participation, the marginal effects are calculated. The third column of Table 6 shows the calculated probability at the sample average for the explanatory variables affecting participation. For dummy variables, the marginal effect is the effect of going from 0 to 1.

Table 6 shows that quantitative water scarcity, technological aspects of farming and pumping and water quality are the major influential factors in the logit model. From the long list of farmer characteristics, the only significant variable in the model is the dummy variable which shows occupations of respondents in addition to farming. On average, having other occupations increases the participation likelihood by 12%. The only variable which cannot be simply explained is the insurance costs for the previous year, which has a positive effect in the model. Although this variable is insignificant, it could not be eliminated by considering different model selection criteria. In contrast, insurance costs for the current year had no effect in the model.

One of the most striking results of the model comes from the two dummy explanatory variables. A farmer who transfers water from other wells to the target farm or transfers water from a target well to other farms (if such a possibility exists), is 31% more likely to buy water, which simply reflects farm water shortages. On average, farmers with an additional non-farm occupation are more likely to participate in the water market by 12%. For every further plot of fragmented land, the farmer is 2.6% more likely to buy water. For a 1-year increase in the average age of a garden, the probability of participation decreases by 0.67%. For each extra 1,000 cubic metres of water quota granted per hectare, there is a decrease in the probability of participation by 1.3%; the significance of increasing water quotas becomes clear when one considers that volumes may be hundreds or thousands of cubic metres. A one metre increase in the depth of the water table increases the probability of participation by 0.31%. A yield increase of one ton dry pistachio per hectare encourages participation by 9.3%. A 1% increase in the share of labour costs, as a proportion of total annual variable costs, reduces the likelihood of water market participation by 0.5%. Labour costs were the most significant of all costs.

An explanation of our quality variables is required. As mentioned before (section 4.3), a single unit increase in EC of 1 μS/cm has a limited impact on water quality. EC was significant in the logit model, however its probability effect was very low. Therefore we have converted the EC variable to dS/m, or 1,000 μS/cm. A one unit increase in dS/m decreases the probability of buying water by 2.25%, which we consider to be a low effect as 1,000 μS/cm is such a large change that it occurs rarely. A similar consideration applies for pH, since pH is a logarithmic scale variable and therefore the difference between pH 7 and 8 is equivalent to changing river water quality to that of sea water, which is unlikely. Therefore the 21% reduction in the probability of buying water associated with a one unit change in pH can be considered of major importance. It shows that the ‘base’ type of water (pH >7) is a discouraging factor for water market participation. Table 7 shows the results of classification analysis. The results show that the logit model predicts the probability of 97% of non-participation and 50% of participation in water buying correctly. In spite of the low number of water buyers compared to non-buyers, the goodness of fit is acceptable.

15 Water transfer is different from water trade. In many cases, the farmer has fragmented lands which are irrigated from different wells. Due to the geographical position of these wells, sometimes the farmer has the chance to transfer water among his fragmented fields which are irrigated from different wells. Water transfer refers to this phenomenon and it is not water trade.

16 The average level of the total water quota of the farms in the sample is around 39,000 cubic metres and the standard deviation is around 62,000 cubic metres.
5.2.1. Spatial autocorrelation. As farms have proximities to both groundwater (a hydro-geological variable) and neighbouring farms (a social variable), spatial autocorrelation could exist between these two variables. A farmer’s decision to participate in the water market could be influenced by the decisions of neighbouring farmers, or the error term in the logit model could be spatially correlated. Therefore, the Moran I test was used to test the spatial autocorrelation among the residuals. Inverse distance was used to establish a spatial weight matrix. As sample residuals are not appropriate criteria in GLMs, Pearson residuals and deviance residuals are checked with the Moran I test. No spatial autocorrelation was found in the model.

6. Discussion and conclusion

Despite the lack of regulation, we could identify a spot water market in the study area. The results show that this market is small and accounts for a limited share of water used for irrigation. Smallholders are the main participants in the market and water distribution patterns can affect the size of this market. Technological factors and environmental factors are more significant factors within this water market than farmer characteristics, household members, or social characteristics. The latter group of variables are not significant factors in the logit model. In accordance with the former literature (Wheeler et al., 2009, 2010), these results confirm that the Rafsanjan informal groundwater market is at the mature stages of water trade. The development of monoculture and the reality of market-oriented agriculture in Rafsanjan may explain the importance of profit-driven factors and farm level factors found. Interpretation of Table 6 shows that water quantity factors affect the model more than water quality factors, which shows water scarcity is more important within the study area than quality. The groundwater depletion effect on the participation decision is an interesting finding of this study. The participation decision is not defined only by the farmers’ level of water quotas, but also by reservoir overall depletion levels. That means in a market setting, the reservoir in situ value becomes an important issue for the users. This suggests that groundwater depletion in areas with good water quality may result in an expansion of spot water markets. Furthermore, technical innovations affecting productivity can encourage spot water market expansion. The results show that farmers with a higher level of productivity per hectare are more likely to participate in the water market. It means that the water market is an efficient tool for devoting more water to a higher level of production and implementation of policies for increases in water productivity can increase the level of participation in the water market. According to former studies, heterogeneous crop pattern (Schoengold & Zilberman, 2007) and heterogeneous pumping right ownership (Garrido & Livingston, 2003) are essential for a successful water market. Although this region specialises in one crop (pistachio) and land size is not a significant variable in the model,
we recognise a heterogeneous pattern of water quota ownership which is a significant variable inside the model.

Regional labour market factors such as labour costs can affect the decision to participate in the water market. Increases in labour costs negatively affect water market participation rates. However, other variable costs do not affect the model. This difference could be largely due to the high labour intensity of pistachio production. It is therefore likely that labour efficiency improvements or technological adaptations that reduce labour costs might encourage water market participation. Although the increase in the age of the trees reduces the participation decision, the size of the effect is very low. It shows that increases in the age of the trees in the study area will not affect the participation dramatically. The reason for this could be an increased water uptake ability with increasing root depth in deeper soil layers. As many farmers are aging, probably the land and water ownership will be more fragmented, which may be another argument for possible market expansion in the future. The significant effect of having other jobs on market participation shows that if income sources of the residents and farmers increase as a result of any regional industrial change or project implementation, the spot water market will expand more. Using other wells is a key factor affecting participation in the water market. Therefore, if the legal and institutional barriers for groundwater transfer are eliminated or reduced, we can expect a higher level of participation in a groundwater market. The high level of significance of this variable shows the potential is large enough for groundwater market expansion to occur by relaxing conveyance and water transfer possibilities.

In this paper we studied factors affecting farmers’ decisions to participate in a fragmented spot water market in the Rafsanjan aquifer of south-eastern Iran using the logit model. The results show that a spot water market exists mostly for use by smallholders. Moreover, the volume of water traded within this market is relatively small. Water quantity factors affect the decision to participate more than water quality factors. The results show that the spot water market probably will be expanded in the future considering factors that significantly affect this model. Regulating the groundwater market may encourage water trade expansion among farmers through the relaxation of current limitations on water use, water transfer and land laws, since there is evidence that the area already has the potential for a more expanded water market.

One of the limitations of this study is the short study period. We have access only to data from a single year which naturally limits the reliability of our results. However, the precipitation situation in Rafsanjan is not variable from year to year and the depletion of the aquifer will continue if a substantial political decision for a change is not taken. Therefore, the results of the statistical analysis and the discussion still provide a valuable contribution to understanding the informal groundwater situation. It must be added that the farmers in study area have never answered positively that they sell water. This behaviour could be due to the legal restriction on water permits that forbids any usage of water deviating from the permit’s stipulations. Therefore, the response to buying water can be obtained more easily through a survey, as is the farmers’ answer to the question regarding water sales. With the availability of possible answers to the water sale question, the factors that affect the decision to sell can be studied. This is also another area of further research.

Future studies could analyse factors affecting the WTP in this fragmented market in order to assist groundwater valuation research. Of regional interest might be an institutional study of groundwater regulations and laws to encourage the expansion of water markets. Another area of research is formal water market expansion without destroying the actual or current norms in informal spot water markets.
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References


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