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Assessing the impact of water price reform on farmers' willingness to pay for agricultural water in northwest China

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ABSTRACT

A water price increase has been used as an effective method to guarantee national water security and maintain national food security in China. The reasonableness of the water price has a direct influence on people's attitude, behavioural decision regarding willingness to pay, and motivation for water conservation. A double-bounded dichotomous choice contingent valuation method was used to assess the impact of integrated agricultural water price reform on farmers' willingness to pay for irrigation water in northwest China. The estimated mean willingness to pay in the study area was 0.144 RMB/m^3. A comparison showed that higher education and longer experience in farming were likely to result in a higher willingness to pay in the study area. Participants who had a higher awareness of water price reform showed a higher likelihood of agreeing to higher bidding. Those who thought the current water price was lower had a higher willingness to pay for irrigation water. Participants who considered agricultural water resources to be scarce in the area also had a higher willingness to pay. In contrast, the bidding variables were negative and significant at the 1% level, showing that participants were more inclined to reject a higher bid. Meanwhile, the older the participant, the less they were willing to pay. An unintended finding was that participants' willingness to pay decreased if they chose to use water-saving technology. One possible explanation was that the investment in the construction of the infrastructure (such as pipes and pumps) may have exacerbated farmers' burden and may not have resulted in any benefits to them. Based on the results of this paper, a related optimization policy was presented for water price reform.

1. Introduction

Water scarcity is increasingly becoming an issue both in developed and developing countries and is hindering social and economic development worldwide, particularly in semi-arid areas (Feng et al., 2017). Climate change has disrupted previously stable cycles of snow, rain and storms, resulting in an unpredictable natural supply of water, and the relative speed of the transition to such unstable global water conditions has surprised governments and companies alike (Schaefer et al., 2019). A recent study showed that there are at least more than 800 million people lacking a safe supply of freshwater and 500 million people are increasingly near this situation throughout the world (Cheng et al., 2019). The emerging water crisis is becoming among the most serious problems facing humans in the 21 st century (Zhao et al., 2017) throughout the world. As the largest developing country in the world, China's situation in many respects exemplifies the global picture, particularly water scarcity in northern part of the country (Wu et al., 2015). The water resources per capita is less than a quarter of the world's average, and water shortage in northwest China is more serious than that in other regions. As in many developing countries, irrigation has played an unsurpassed role in the sustained growth of Chinese crop production in China (Shen and Lin, 2017). Irrigation in regions of limited rainfall in northwest China dominates water use, often accounting for greater than 60% of total water use (MWR, 2015). However, with the growth of the global population and the demand for food, as well as competition between different water sectors, the pressure on irrigation systems to act as major consumers to release water for other uses and improve performance in these areas has increased (Sun et al., 2016). In addition, due to the acceleration of industrialization and urbanization, as well as environmental challenges such as climate change and water pollution, the shortage of irrigation water in the region is increasingly serious (Wang et al., 2018). Therefore,

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future irrigation water supply will continue to decrease in northwest China. Solutions to the potential problems of irrigation water supply have been focused on water resources demand management in China (Zhao et al., 2016).

With the increasing demand for global water resources, the increasingly serious problems faced by scholars and policymakers have attracted the interest of some analysts, e.g., Li et al. (2018) to recommend changing crop water requirements in water-deficient areas. Castellano et al. (2008) suggested changing water supply management into water demand management to solve the problem of the current water crisis. There is clear theoretical and empirical evidence from several scholars that water price leveraging is considered as the most effective mean of water demand management to advance water allocation and water conservation (Pesic et al., 2013; Tortajada et al., 2019). Water pricing can show the economic value of this valuable resource and encourages water users to more wisely utilize water resources. Furthermore, pricing can guide farmers to adopt irrigation technologies with high irrigation efficiency or to change to a more productive cropping pattern (Schoengold et al., 2006). Previous research findings in several countries have shown the demand for irrigation water is inelastic because the price is too low, and only when the price of water is increased to a relatively high level does, the pricing promote water conservation (Sidibé et al., 2012; Berbel et al., 2018). The Chinese government has always attached great importance to the issue of water pricing. Although agricultural water demand is high in northwest China, the irrigation water price is relatively low, accounting for only one-third of its production cost. In these regions, agricultural water prices are charged mainly on a non-volumetric basis. For example, because of the lack of water metering facilities, water charges are paid according to the size of the irrigation area. Thus, if the price is low, this leads to a lack of water-saving incentives for farmers and affects their motivation to pay the water fee (Huang et al., 2010). In particular, the low water prices lead to the coexistence of a water resources shortage, waste and side effects on farmers' income, the irrigated area is in a serious deficit management state in northwest China (Liu et al., 2019). In addition, the low price of water also result in insufficient maintenance and management of irrigation channels including serious seepage. Instead, it has affected farmers' motivation to pay for the water, thus forming a vicious cycle of poor management of the water supply system. Thus, the current water price policy cannot systematically reflect water commodity attribute. Therefore, integrated agricultural water price reform in China is imperative (Yu and Shen, 2014).

Hopefully, the No. 1 document (refers to the first document released annually by the Central Committee of the Communist Party of China), which has a programmatic and guiding position in the work of the country throughout the year, can improve the situation. The problems mentioned in the No.1 document are the urgent problems the need to be solved by the country throughout the year. The No.1 document issued by the central government in 2017 and calls for promoting the comprehensive reform of agricultural water prices and improving the water prices formation mechanism and the inventive mechanism for agricultural water conservation. One of the main points of the document is to increase the water price to the price needed to meet the operating and maintenance costs of a water supplier within 10 years (Zhang et al., 2017). Under such a policy background, the implementation of a ladder water price system will promote agricultural water resources conservation and improve water use efficiency (Shen and Wu, 2017). Although increasing water prices can induce farmers to save water, it will further weaken farmers' motivation for farming and affect the originally fragile agricultural production system. Aidam (2015) showed that increasing the water price will lower farmers' incomes as a result of adjusting their planting structure and increasing the agricultural production input. Liu et al. (2015) reported that increasing agricultural water prices will undoubtedly be in conflict with poverty alleviation in rural areas in northwest China. Thus, water pricing needs to be carefully set such that water is affordable to the water user while also being financially sustainable for the supplier (Nikouei and Ward, 2013). In consideration of the potential impacts of the proposed water price increase, as the main users of agricultural irrigation water, farmers' attitudes to water prices and their willingness to pay (WTP) should be considered in the formulation and implementation of water pricing reform.

In areas where water price reform needs to be implemented to achieve sustainable use of water resources, estimates of farmers' WTP are needed to assess the transmission effect of increasing water price. Toshisuke and Hiroshi (2008) evaluated the economic value of irrigation water to urban and non-urban users in Japan and indicated that rural users who depended on water resources for household use and to maintain agricultural income had a higher WTP for water than that of urban users. Baghestani and Zibaei (2010) reported that farmers using groundwater as the only source of water have a higher WTP compared to that of farmers that used both surface and ground water based on the continent valuation method (CVM). Storm et al. (2011) modelled demand for irrigation water in the Moroccan Drâa Valley based on the CVM and indicated that farmers' true willingness to pay (WTP) was higher than the current water prices in the region, but those authors also noted that only small increases in cost would be politically tenable. Mesa-Jurado et al. (2012) suggested that the WTP of farmers based on the CVM in the Guadalquivir River Basin in southern Spain increased under conditions of water scarcity when farmers perceived the impact of guaranteed water supply to positively affect their own welfare. Tang et al. (2013) estimated farmers' WTP for water using the CVM and the results showed that the current price of water in the agricultural sector is lower than the farmers' WTP because farmers are reticent to pay for irrigation water. Alcon et al. (2014) suggested that farmers' WTP are twice their current irrigation water price to ensure water supply reliability, but they are averse to any other institutional changes including water price increases. Guilfoos et al. (2019) conducted a contingent valuation study and found a mean WTP for water filters of $ 18 USD for the general population and an estimate near zero for subjects with a perceived “very clean” water quality. In addition, WTP impact factors are also proposed base on WTP analysis models. WTP for water has significant positive correlations with subsidy policy, top dressing time, age, scale, irrigation investment and net income, while work time and informant sources have a negative impact (Zhou et al., 2018). Bozorg-Haddad et al. (2016) reported that, with water rationing, farmers' WTP and water use are affected by the water price, water shortage distribution, irrigation system type and crop type. Knapp et al. (2018) also identified a set of factors that influence producers' WTP and indicated that a higher awareness of water scarcity seems to predict increases in producers' WTP for irrigation water. Guerrero-Baena et al. (2019) suggested that farm characteristics related to irrigation water dependency (water availability risk exposure) significantly determine farmers' WTP for to improve water supply reliability, showing a positive relationship. Moreover, the results also showed that socio demographic variables influenced farmers' WTP. Although there is an increasing consensus on farmers' WTP and its influencing factors for different purposes, few issues relate to their response to an irrigation water price increase when pricing reform is implemented.

The aforementioned literature has resulted in important advances in the analysis of farmers' willingness to pay for water. Despite these contributions, we have found few studies (Garrone et al., 2019; Masserini et al., 2018) that appeared to pay attention to the following: (1) differentiated pricing for different attitudes and willingness of participants; (2) a reasonable grasp of the scale of the water price adjustment; and (3) the influence of participants' subjective factors on their willingness to pay. To fill this gap, we used a double-bounded dichotomous choice contingent valuation method (DBDC-CVM) to estimate the impact of the differentiated water price on farmers' willingness to pay and its influencing factors for irrigation water in northwest China. Our WTP findings are useful to policy makers and agricultural producers around the world where irrigated agriculture is critical to the economy and adaptation to increasing water price is a concern. In particular, the results are important for evaluating the viability of water price reform to increase the agricultural water price and are helpful in providing a scientific and reasonable reference for facilitating the comprehensive reform and water use efficiency increasing in China. In addition, the results can effectively improve the level of Chinese agricultural water resources management and can be of great value in promoting the nation's economic and ecological sustainable development. Our analysis also examined which factors had predictive power for influencing participants' WTP from the subjective and objective angles. Both our research design and research findings are significant in understanding the potential for the implementation of water price reform to achieve sustainable use of agricultural water resources.

2. Policy background

China continues to deal with severe levels of water shortage and water pollution. Simultaneously, rapid socioeconomic development, urbanization and industrialization have threatened the sustainable use of water resources. This phenomenon is gradually driving the growth of water use by industry and urban residents, and also increasing competitive consumption of water resources by agriculture and other sectors. Under this background, the Chinese government has been tasked with a pilot program for the further enrich the theory of agricultural water resources management.

In 2012, China conscientiously began carrying out the strictest water resource management (SWRM) system that was proposed in 2011. This emerging SWRM approach was positioned in the 2011 Central Committee No. 1 Document of the Communist Party of China as a strategic move to achieve a sustainable utilization of water resource and human–water harmony. SWRM is symbolically dubbed 'three red lines', which represents a policy of: (1) the control of the development and utilization of water resources, and total water consumption for agriculture at the end of 2030 should not overtop 700 billion m^3 (2) the control of water use efficiency, and the effective utilization coefficient of farmland irrigation water will be raised to more than 0.6 and (3) the restriction of pollutants in water function areas, and the water quality standard in water functional areas will be increased to more than 95% by 2030 (Ministry of Water Resources, 2012).

In 2016, the Office of the State Council issued an official document on agricultural pricing reform: within 10 years or so, it will establish and improve a pricing mechanism for agricultural water that can reflects the cost of water supply in a reasonable way, which is conductive to water conservation and institutional innovation. And the prices can be raised to the full cost level in areas where water resources are scarce and users have strong affordability (Office of the State Council, 2016). In addition, an investment and exact subsidy mechanism which is corresponding to the formation mechanism of agricultural water price will be established (Office of the State Council, 2016). Although theoretically, price mechanism is key instruments to increase the efficiency of water resources utilization, farmers' attitudes should also be considered. Without this, the result of the pricing reform may have a series of unexpected effects. Therefore, in this paper we will know farmers' WTP for irrigation water under the pricing reform.

3. Methodology

Based on the design of the research, a data flow diagram (Fig. 1) was developed to better present the methodological steps followed during the process of the study.

3.1. Study area description

The study area of this paper is Xi'an (Fig. 2), which is the main agricultural area in the Weihe River basin in China. It is the capital of Shaanxi province, lying in the center of the Guanzhong Plain in the northwest of China. According to the Xi'an City Statistics Bureau (SBXC, 2013), the city covers an area of 1.01×10^6 ha and encompasses 11 districts and 2 counties under its governance. Except for Lianhu, Xincheng and Beilin districts because they have no agricultural development, the other 8 districts and 2 countries are typical irrigated agricultural area. The total population of Xi'an city is 8.59 million residents, of whom about 27.95% are located in rural areas. The average annual rainfall is 426.70 mm, however, rainfall generally occurs outside the growing season (October to May). And during the growing season the insufficient rainfall forcing farmers to rely heavily on pumping groundwater to irrigate the crops. The water resources per capita of this region are 278 m^3 approximately 1/6 of the national average, which is only 1/24 of the world average level. Moreover, the spatial distribution of water resources is extremely uneven. The area of the farmland in Xi'an city is 246,000 ha, of which about 74% is irrigated.

Following the economic development and the increase of residents' income, the water consumption of industrial and living sectors has been increasing continuously, water consumption competition between sectors is increasingly fierce, and the water supply for agriculture will continue to decline. Due to climate and the traditional economic development pattern are changing, the total water resources in various river basins have been significantly reduced, so farmers have no choice but to extract more groundwater. For decades, approximately 55.16% of irrigation water has been obtained via deep groundwater exploitation. In order to keep its current normal industrial and agricultural production, the city has to draw 127.75 million m^3 of groundwater every year. The excessive exploitation of groundwater not only causes land subsidence but also leads to soil salinization and vegetation degradation and other ecological problems in this study area.

This is an area with such a shortage of water resources, however, the water use efficiency is still very low. One explanation for the phenomenon is that agricultural water price is low, which causes the ineffectiveness of price mechanism to effective regulate water management and allocation. At the same time, it is imperative to recognize the product attributes of water resources and to reflect the scarcity of water resources through the market mechanism, for the purpose of promoting water-saving through price leveraging (Guo, 2006). However, as the main users of agricultural irrigation water, farmers' attitudes to water price and bearing capacity of water price should be considered in the formulation and implementation of water pricing police process. That is mainly because water rate is the most important input in agricultural farming production.

3.2. Econometric model

The research was conducted based on DBDC model, and this is a derivation of the single-bound dichotomous choice (SBDC) model.

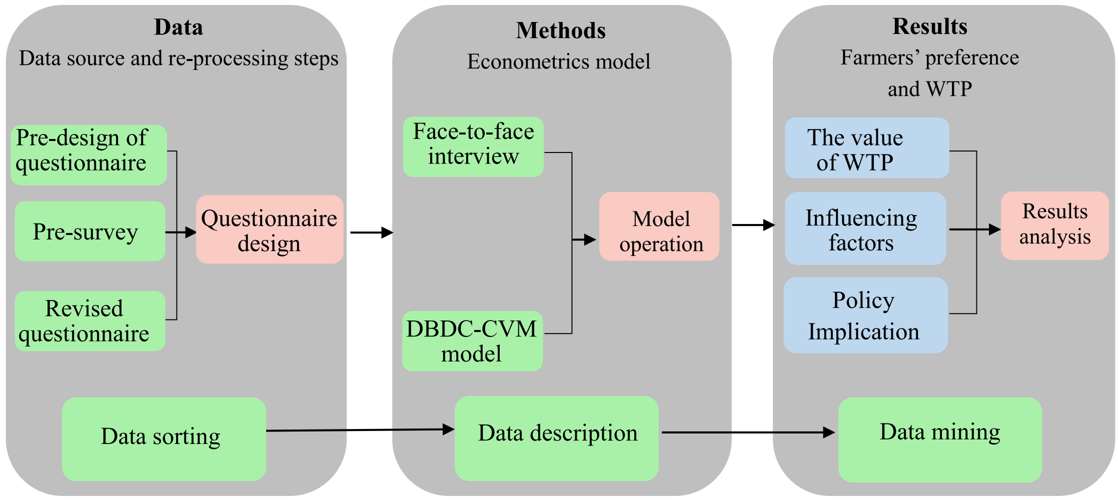

Fig. 1. Conceptual framework and workflow for the assessment of water price reform on farmers' willingness to pay and its influencing factors.

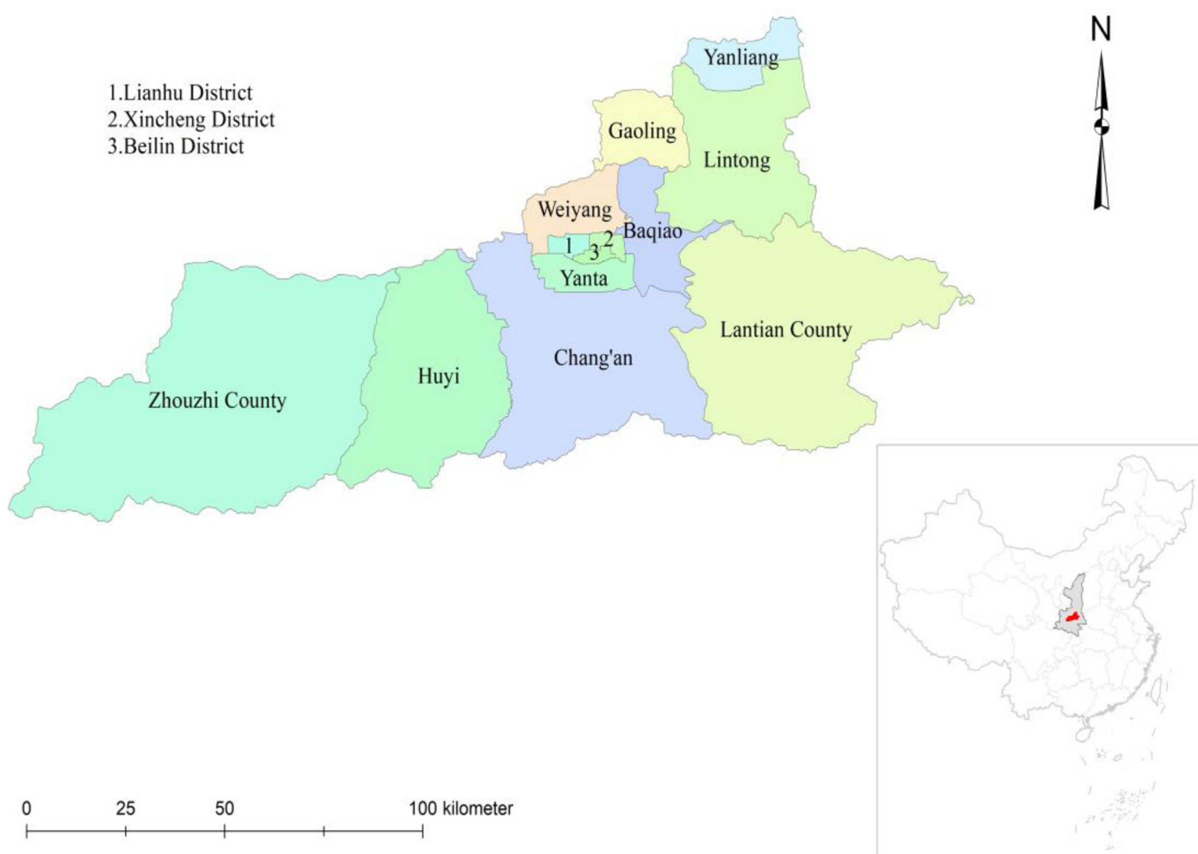

Fig. 2. Map of the location of the study area.

As for the SBDC model, if the participants would like to pay only one single bidding for a service they will answer "yes or no". And the likelihood of answering "yes" to the offered bidding is written by:

$$P_i^Y\left(b^k\right) \le \Pr\left\{b^k \le \text{maxWTP}\right\} \quad (1)$$

On the contrary, the probability of "no" answering is$1 - P_i^Y(b^k)$, where $b^k$is the given bidding (Hanemann et al., 1991). While a participant's WTP is higher than the given bidding and the equation can be proposed (Koss and Khawaja, 2001):

$$\pi^Y = \frac{1}{1 + e^{-\left(\alpha + \beta b^k + \sum \delta_j Z_j\right)}} \quad (2)$$

where$\pi^Y$is the likelihood of the yes answer,$\beta$is the bidding coefficient, and $\delta_j$is the coefficient of j control variables, Z.

In the DBDC model, each participant should response to two successive given biddings. When a participant replied “yes” to the given bidding, then the investigator will propose a greater bidding. In contrast, if the participant replied “no”, and a lower bidding will be given. Therefore, each participant falls into the following four classification, yes to yes (YY), yes to no (YN), no to yes (NO), and no to no (NN). And the likelihood of the four answers can be defined as:

$$\pi^{YY}\left(b_i^I, b_i^U\right) = \Pr\left\{b_i^I \leq \text{maxWTP and } b_i^U \leq \text{maxWTP}\right\} \quad (3)$$

$$\pi^{YN}\left(b_i^I, b_i^U\right) = \Pr\left\{b_i^I \leq \text{maxWTP and } b_i^U \geq \text{maxWTP}\right\} \quad (4)$$

$$\pi^{NY}\left(b_i^I, b_i^L\right) = \Pr\left\{b_i^I \geq \text{maxWTP and } b_i^L \leq \text{maxWTP}\right\} \quad (5)$$

$$\pi^{NN}\left(b_i^I, b_i^L\right) = \Pr\left\{b_i^I \geq \text{maxWTP and } b_i^L \geq \text{maxWTP}\right\} \quad (6)$$

where the b_i^I, $b_i^L$and b_i^U represented the initial, lower, and upper bidding respectively, and i is the participant index. And the DBDC model allows for a bounded interval (Eqs. (4) and (5)), or maximum and minimum bound (Eqs. (3) and (6)) (Nayga et al., 2006). Using Eq. (2), Eqs. (3)–(6) are changed:

$$\pi^{YY} = \frac{1}{1 + e^{-\left(\alpha + \beta b_i^U + \sum \delta_j Z_j\right)}} \quad (7)$$

$$\pi^{YN} = \frac{1}{1 + e^{-\left(\alpha + \beta b_i^I + \sum \delta_j Z_j\right)}} - \frac{1}{1 + e^{-\left(\alpha + \beta b_i^U + \sum \delta_j Z_j\right)}} \quad (8)$$

$$\pi^{NY} = \frac{1}{1 + e^{-\left(\alpha + \beta b_i^L + \sum \delta_j Z_j\right)}} - \frac{1}{1 + e^{-\left(\alpha + \beta b_i^I + \sum \delta_j Z_j\right)}} \quad (9)$$

$$\pi^{NN} = \frac{1}{1 + e^{-\left(\alpha + \beta b_i^L + \sum \delta_j Z_j\right)}} \quad (10)$$

The log-likelihood function for the DBDC model, L^{DB} is defined as:

$$L^{DB} = \sum y_i^{YY} \log\pi_i^{YY} + \sum y_i^{YN} \log\pi_i^{YN} + \sum y_i^{NY} \log\pi_i^{NY} + \sum y_i^{NN} \log\pi_i^{NN} \quad (11)$$

where $y_i^{XX}$is a metrics variable of the i^{th}participant.

According to Koss and Khawaja (2001), based on Eq. (2) and the DBDC model, the WTP can be estimated as:

$$\text{WTP} = \frac{\ln\left(1 + e^{\left(\alpha + \sum \delta_{ij} Z_{ij}\right)}\right)}{-\beta} \quad (12)$$

3.3. Data and variable definitions

Our goal was to estimate the WTP for irrigation water under a price increase using the CVM by developing an appropriate WTP survey. Potential survey participants were irrigation water users in the study area. Considering that some county households did not have internet in their homes, online communication was inconvenient and the response rate was low, while face-to-face communication could be more friendly and effective in presenting our ideas, and its response rate is higher. Thus, research data were acquired through face-to-face interviews completed by Shaanxi Normal University and the Chinese Academic and Sciences. Considering the constraint of participants' time and understanding, the questionnaire was designed to be concise and avoid open-ended answers. The survey had nearly 50 questions that will took participants 20–30 min to complete. The concern with the CVM was the reliability and validity of the responses. Therefore, the potential deviations and their solutions of the questionnaires are shown in Table 1. To minimize deviations, 200 questionnaires were conducted as a pre-survey. The questionnaires were then revised according to the pre-survey results. A total of 1000 questionnaires were completed in the 8 districts and 2 counties; 43 of the questionnaires were removed due to the vague understanding regarding WTP questions. Therefore, analysis was carried out using 957 questionnaires in this study. The survey was conducted during July and August of 2017.

The face-to-face interview had four sections. The first section of the questionnaire was an instruction. This section was designed to introduce the identity of the investigators and to explain the purpose of the interview and the main contents of the interview to eliminate the participants' hesitancy and dispel their misgivings.

The second section addressed the socio-economic status of the participants. The section involved the participants' gender, age, family size, education level and income level. The variable definitions and the results of the statistical survey are included in Table 2. The socio-economic survey of the farmers showed that 66.98% were male and 33.02% were female. The majority of the participants (66.8%) were between 38 and 68 years old, while 22.2% were in the 18–38 years old category; 5% were under-18 years old and 6% were 68 years old. Classification of participants based on their education showed that 144 (15%) of the farmers had a bachelor's degree or higher, 28% (265) of the participants' highest educational attainment was high school, 451 (47%) did not have 12 years of compulsory education, and 97 (10%) were illiterate. Three quarters of the farmers lived in a joint family system (two children or more), while one-fourth of the participants followed by the adopted nuclear family system (one child). The average number of years of planting experiences was 23.57 years, and ranged from 0 to 49 years. A total of 64.2% of the participants undertook agriculture followed by both agriculture and business or business (35.8%). The gross income and the farming shares were all proposed to assess the livelihoods of the participants. Regarding the size of the holding, 61.75% operated in cash crops followed by 38.25% in food crops.

Table 1
The potential deviations and their solutions of the questionnaire.

Deviation types	The method to reduce deviation
Sampling deviation	Random selection of respondents from farmers to avoid the specialization of the surveyed farmers
Non reaction deviation	Questionnaire was designed to be concise and give the opportunity to express uncertainty to the respondents
Stating point deviation	Pre-investigation
Information deviation	Farmers had a good understanding of the local irrigation water, and the questions about the price of water can be answered well
Interview method deviation	Face-to-face interview
Investigator deviation	All the investigator were familiar with the questionnaire, filled out the questionnaire and discuss it before the investigation
Strategic deviation	Emphasizing the importance of water price for farmers and guiding the real answers for the respondents

Table 2
Variable definitions and summary statistics.

Variable	Description	Mean	St.Dev.	Min	Max
age	Respondent rating of the age in the area, from 0 = under-18, 1 = 18–28 to 6 = above 68	3.0172	1.5960	0	6
Education	0 = education level is lower than Bachelor' degree, 1 = not	0.1542	0.3577	0	1
Household labor force	Total members of household labor force	3.0773	1.0581	1	5
Years of farming	Total years of farming experience	23.57	11.20	0	49
Gross income	1 = Total income is higher than 100,00RMB and smaller than or equal to 500,00 RMB, 0 = not	0.6888	0.4694	0	1
Percent farm income (%)	Percent of gross income from faming	68.17	24.67	0	100
Total hectares	Total irrigated in 2017	0.2474	0.1207	0	0.64
Percent cash crops (%)	Percent irrigated cash crops production of total hectares in 2017	61.75	26.69	0	100
Percent food crops (%)	Percent irrigated food crops production of total hectares in 2017	38.25	26.69	0	100
Irrigation water shortage	Water scarcity from 0 = no deficit to 4 = severe deficit	1.71	0.96	0	4
Farmers' views on current water price	Respondent rating of the price problem from 0 = too high to 4 = too low	2.82	0.9	0	4
Awareness of water price reform	1 = is aware of agricultural water price reform, 0 = not	0.4828	0.5000	0	1
Water saving technology utilization	1 = has used the water conservation technology, 0 = not	0.7398	0.4390	0	1

The majority of the famers belonged to the either middle or lower socio-economic class. This particular group of farmers will have a significant impact on the average WTP values as their WTP for water is typically expected to be low.

In section 3, the questionnaire addressed the participant's general consciousness of water price. Farmers' perception regarding irrigation water availability assumes an importance in their WTP. Thus, the participants were initially asked "do you have an irrigation water shortage problem on your farm?" Only 22% of the participants thought their farms lack water resources and 78% of the participants indicated that the water they received was sufficient to harvest a successful crop. We then asked the participant "do you think the water price is reasonable on your farm?" A total of 569 (59.46%) of the participants ranked the water price as a two or lower, believing the water price was high on their farms. Another two variables were proposed for water pricing reform. One variable aimed to determine the consciousness of options for the reform; therefore, participants were questioned when they were aware of water pricing reform that the water price increase is to cover the operation and maintenance costs of the water supplier. A total of 47% of the farmers reacted positively while explaining that an increase in irrigation water price might effectively enhance water use. Second, participants were also asked if they would like to use water saving irrigation technology under the reform. In contrast, approximately 74% of the participant indicated that they would not use the water conservation technology for irrigation on their farms because of the technological installations or the equipment expenses. Table 2 lists all the variable definition and summary statistics.

Section 4 included questions regarding willingness to pay for the irrigation water (Table 3). Seven sets of questions were applied in the investigation, and every question began with a different stated value (0.110RMB/m^3, 0.121RMB/m^3, 0.132 RMB/m^3, 0.143 RMB/m^3, 0.154 RMB/m^3, 0.165 RMB/m^3, and 0.220 RMB/m^3). The first 0.110 RMB/m^3 WTP values were determined based on our pre-survey result throughout Xi'an city. The range of WTP values was proposed by increasing the current water pricing (0.110 RMB/m^3) by 10% (0.121RMB/m^3), 20% (0.132 RMB/m^3), 30% (0.143 RMB/m^3), 40% (0.154 RMB/m^3), 50% (0.165 RMB/m^3) and 100% (0.220 RMB/m^3).

Table 3
DBDC bidding sets and the successive questions asked during the interview.

	Initial Bidding	Upper Bidding	Lower Bidding
Biding Set 1	0.110RMB/m^3	0.165RMB/m^3	0.055RMB/m^3
Biding Set 2	0.121RMB/m^3	0.182RMB/m^3	0.061RMB/m^3
Biding Set 3	0.132RMB/m^3	0.198RMB/m^3	0.066RMB/m^3
Biding Set 4	0.143RMB/m^3	0.215RMB/m^3	0.072RMB/m^3
Biding Set 5	0.154RMB/m^3	0.231RMB/m^3	0.077RMB/m^3
Biding Set 6	0.165RMB/m^3	0.248RMB/m^3	0.083RMB/m^3
Biding Set 7	0.220RMB/m^3	0.330RMB/m^3	0.110RMB/m^3
Question 1	Would you like to pay the **Initial Bidding** for agricultural water?		
Question 2	(If the answer is positive to question 1) Would you like to pay **Upper Bidding** for agricultural water?		
Question 3	(If the answer is negative to question 1) Would you like to pay **Lower Bidding** for agricultural water?		

One set was randomly chosen from the seven groups to reduce the starting point deviation (Aprahamian et al., 2010). Every participant was asked the first question "would you be willing to pay RMB/m^3 to purchase water from an irrigation department?" When the participant said "yes" ("no"), this question would be asked again in 50% increments to the higher (lower) bidding. During this interview, we also set aside a time interval of 3–5 min for the two consecutive bidding with the purpose of reducing the acquiescence deviation (Lee et al., 2015). As the irrigation water price has been implemented for quite a long time in the area investigated, famers have fully accepted it. In the pilot survey, all the farmers agreed to pay for the irrigation water; therefore, there was no design to distinguish between 0 bidding and protest bidding in the questionnaire. Table 4 shows the replies at different bidding levels.

4. Results and discussions

4.1. Farmers' preferences and willingness to pay (WTP)

Willingness to pay was estimated for each observation by using

Table 4
Numbers of positive and negative answers at every given bidding level (RMB/m^3).

	Bid	Yes	(%)	No	(%)	Total response
Bid Set 1	0.055RMB	55	0.89	7	0.11	
	0.110RMB	123	0.66	62	0.34	185
	0.165RMB	77	0.63	46	0.37	
Bid Set 2	0.061RMB	38	0.66	20	0.34	
	0.121RMB	96	0.62	58	0.38	154
	0.182RMB	34	0.35	62	0.65	
Bid Set 3	0.066RMB	54	0.68	25	0.32	
	0.132RMB	87	0.52	79	0.48	166
	0.198RMB	26	0.30	61	0.70	
Bid Set 4	0.072RMB	41	0.65	22	0.35	
	0.143RMB	65	0.51	63	0.49	128
	0.215RMB	22	0.34	43	0.66	
Bid Set 5	0.077RMB	39	0.61	25	0.39	
	0.154RMB	44	0.41	64	0.59	108
	0.231RMB	13	0.30	31	0.70	
Bid Set 6	0.083RMB	30	0.73	11	0.27	
	0.165RMB	58	0.59	41	0.41	99
	0.248RMB	27	0.47	31	0.53	
Bid Set 7	0.110RMB	52	0.67	26	0.28	
	0.220RMB	39	0.33	78	0.67	117
	0.330RMB	17	0.44	22	0.56	

Table 5
The estimated WTP in Xi'an, Yanta district and Zhouzhi county.

Regions	GDP (*10^9 RMB)	Irrigation water price charged (RMB/m^3)	Estimated WTP (RMB/m^3)
Xi'an	7469.85	0.142	0.144[a]
Yanta district	1235.43	0.153	0.158[b]
Zhouzhi county	134.26	0.116	0.098[b]

[a] Mean wiliness to pay.
[b] Median willingness to pay.

Eq. (12), and the results are shown in Table 5. The survey results showed that, of our sampled, the mean WTP is 0.144 RMB/m^3. There were few results from previous research against which we could compare the results of our research. However, the modelled WTP value (0.144 RMB/m^3) was higher than the prices currently paid (0.142 RMB/m^3) by producers in Xi'an city. A comparison was also carried out for Yanta district and Zhouzhi county, which had on average the best and worst economic status in Xi'an city, respectively.

One important finding was that in the Yanta district, the estimated WTP was higher than what most participants currently paid for irrigation water (0.158 RMB/m^3 versus 0.153 RMB/m^3). The Yanta district is the metropolitan area in Xi'an city and has superior socio-economic and geographic position contributing to an increase in the WTP for farmers. The producers' greater water saving consciousness had also been developed resulting in a higher WTP, in accordance with other research (Mu et al., 2016). This finding highlighted the importance of continued outreach by the extension service to increase awareness of the water crisis both domestically and abroad. In contrast, the median WTP was less than the price currently paid by producers in Zhouzhi county (0.098 RMB/m^3 versus 0.116 RMB/m^3). This result showed that increasing water price had hardly encouraged farmers to use water in an effective manner; this information is crucial for the decisions makers. Chen et al. (2014) stated that the new mechanism of 'collect then refund'. This mechanism involved, first, establishing the water price; then collecting the water funds through raising water prices during the irrigation cycle, and, last, calculating water use associations by dividing the water funds by the total land area of the village, determining the refund amount per square meter and distributing the remainder accordingly. The reward and punishment for each farmer was also published in the village and seemed to be more of a prospect than the current increasing agricultural water prices in China. Thus, even in an area economic development where water is most abundant, farmers' WTP for irrigation water is likely to exceed that of the economically underdeveloped area when increasing the water price.

4.2. Drivers of willingness-to-pay for irrigation water

The estimation results of the DBDC model are reported in Table 6. In the model, goodness-of-fit was determined using the advanced comprehensive and sequential classification (Kanninen and Khawaja, 1995). The steps of the sequential classification results were divided into two values: the initial correctly classified cases (ICCCs) and the fully correctly classified cases (FCCCs). An ICCC is defined as an estimated likelihood higher than 0.5, and an FCCC is described as calculating the goodness of fit. The FCCC result is 45.23%, which outclasses the baseline of 13.79% (132 “No, No”) determined by the maximum opportunity criterion. Therefore, compared to all participants who were grouped, the aforementioned methods used accurately ranked more ICCCs in the most common case.

As is known, the marginal effect of the variable about the WTP was indirectly calculated, however, the sign of the estimated coefficient can demonstrate the result. If the coefficient of the bidding variable was positively significant at the 1% level, the participants would probably to say yes to a higher bidding, and the converse was also true. The coefficient of the bid variable was negative and significant at the 1% level, indicating that participants were more likely to say no to a higher bidding. Tang and Xu (2009) also reported that representatives who say yes to the initial bidding will probably reject the higher bidding, consistent with the results obtained in the present study. This result was consistent with the theoretical expectations. There was a significant negative correlation between age and WTP, the estimated coefficient of which was −0.8817. The older the participants, the less they were willing to pay. As shown in Fig. 3, one of the reasons may be that older people have less economic capacity while younger people have more knowledge regarding water resources and have frequent access to water crisis education. Mesa-Jurado et al. (2012) indicated that younger participants likely care more about the future availability of agricultural resources (such as water) and maintaining the viability of their agricultural experience for a long time compared to that of the older participants. It was shown that education level was also a crucial factor affecting farmers' WTP for irrigation water. People with a higher education were more likely to pay. As shown in Fig. 4, participants who had a bachelor degree or above seemed more likely to say yes-yes to the bidding; in contrast, the participants' who had an education level of primary school or below had the lowest WTP percentage and even said no to the initial low bidding. Khan and Damalas (2015) also found that in the Vehari district the farmers who were relatively more educated had a higher mean income and greater risk perception regarding pesticides, had the lower number of a zero WTP when compared to that

Table 6
The estimate results of the DBDC model.

Variables	Coefficient	Standard Error
Intercept	−1.2339	0.9976
Bid	−0.0439**	0.0039
Age	−0.8817**	0.6287
Education	0.6981*	0.7123
Household labor force	−0.3400	0.1195
Years of farming	0.1839**	0.0422
Gross income	0.0030**	0.0011
Percent farm income	0.0029**	0.001
Total hectares	−0.0750*	0.0088
Percent cash crops (%)	−0.1019	0.9433
Percent food crops (%)	0.6574	0.7002
Irrigation water shortage	0.2124*	0.0598
Farmers' views on current water price	0.3730**	0.1056
Awareness of water price reform	1.2005**	0.3576
Water saving technology utilization	−1.0658*	0.5011
Observations	957	
Wald Chi^2	139.31	
$P > Chi^2$	0.0008	
Log Likelihood	−208.0258	
ICCC	59.87%	
FCCC	45.23%	

*Significant at 5%.
**Significant at 1%.

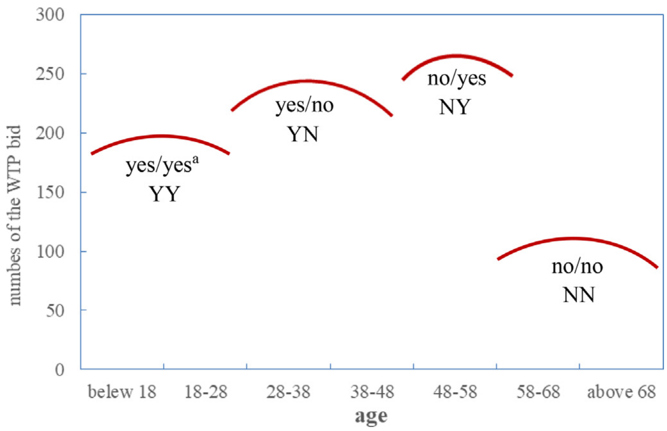

Fig. 3. The numbers of WTP answers for different biddings under varied ages.

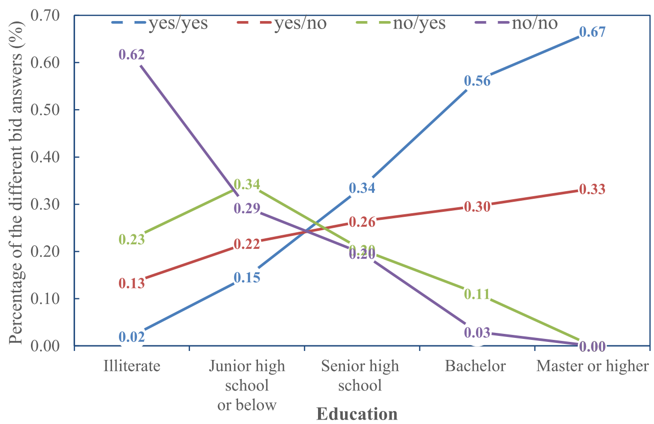

Fig. 4. The percentage of the different bidding answers for WTP under varied education.

of the Lodhran district. Zhang et al. (2019) also indicated that education activities had significantly positive effects on habitual green consumption behaviour for energy or resources conservation, which is also consistent with our results. The reasons were as follows: one reason is that participants with a higher education level had much more knowledge regarding the water resource condition, particularly the water problem both domestically and abroad. However, these people were in a better financial condition.

The estimated coefficient of years of farming experience was statistically significant at 1%. This result may be because that producers would like to exit rather than continue using purchased non-agricultural water if the water price increases to a high level. For young producers, every year of farming experience enhances their dependence on cultivation, reducing the chance of their exit (Knapp et al., 2018). The study also showed that total income and agricultural income had a significant impact on farmers' WTP for irrigation water when the water price was increasing. This finding may be because for farmers who had a high income, particularly a high income from farming, the ability to pay is greater, and they are more likely to invest in agriculture because they can obtain more benefits (Bakopoulou et al., 2010). The coefficients for household labour force were not statistically significant. However, in other research conducted by Chandrasekaran et al. (2009), the medium and large producers had relatively lower WTP when compared to the marginal and small producers, which was inconsistent with the aforementioned studies. The explanation proposed by these authors was that nuclear families make decisions and allocate funds for irrigation water more easily than joint families, and their daily consumption would also be relatively less.

In our study, there was no statistical significance in the proportion of food crops and cash crops planted. Nevertheless, as the total irrigated areas increases, the WTP value for per hectare decreases. Purchasing of agricultural water from irrigated areas was decided not based on intermediate- or long-term farming resolution but on a producer's bottom line. As a result, farmers prefer changing the crop planting structure to buying agricultural water from a water administrative department under the background of a water price increases (Knapp et al., 2018). The coefficients of participants' views on current water prices implied that the participants who thought the current price of water was low had a higher WTP for irrigation water. Farmers with a high willingness to pay are willing to pay higher water prices, thus they tend to think that the current water price is low; farmers with a low willingness to pay are willing to pay lower water prices, thus they tend to think the current price is high. Tang et al. (2013) calculated farmers' WTP, and the results also showed that the agricultural water price is very low and a few farmers were unwilling to pay for irrigation water. The main reason was that those farmers' income was low and they had no ability to pay. At the same time, the farmers were influenced by traditional ideas; the farmers believed that it was the responsibility of the state to provide irrigation, and it should not be borne by farmers.

Coefficients of variables that determine the consciousness of water price reform and water scarcity problems were positively related. As expected, farmers' assessment of their irrigation water deficit was positive at a 5% level and statistically significant, indicating a higher WTP for irrigation water if agricultural water resources were considered scarce. Bozorg-Haddad et al. (2016) also indicated that farmers' WTP for irrigation water during a water shortage was high and was found to be highly variable during sufficient water periods, a conclusion consistent with the findings of our study. These results highlighted the importance of increasing extension efforts to increase awareness of growing and long-term water scarcity in the study area. Farmers who had a higher awareness of water price reform displayed a greater probability to say yes to a higher bidding. This finding was due to those who participated in conservation programmes, such as water price reform, had better access to conservation information and completed production decisions based on the impact of their choices on future periods.

A somewhat unexpected results was that farmer's WTP decreased if they chose to use the water saving technology. In contrast, Tabieh et al. (2015) showed that farmers' maximum WTP for irrigation water was determined based on the irrigation methods used; the water payment ability used in drip irrigation was the highest (JD 0.84 m^{-3}), while the water payment ability used in sprinkler irrigation was the lowest (JD 0.07 m^{-3}). Approximately 60% of the study area was currently broadly irrigated while 40% was drip irrigated or furrow and sprinkler irrigated. This observation may be because the irrigated crops had the lowest value added and profitability. In addition, the investment in the construction of the infrastructure (such as pipe and pump) may have exacerbated farmers' burden and may not have resulted in any benefits. Therefore, farmers preferred to pay higher water prices and were unwilling to pay for more investment in equipment to increase the irrigation efficiency.

5. Conclusions and policy implications

5.1. Conclusions

The central government of China is implementing agricultural water price reform to slow and reverse water shortage; the price is required to cover the operation and maintenance costs of a water supplier within 10 years. When pricing the irrigation water, the farmers' bearing capacity should be considered. The DBDC-CVM was applied to estimate farmers' willingness to pay and its influencing factors corresponding to various water prices.

This research generated an estimated WTP of 0.144 RMB/m^3. Importantly, the value was higher than the prices currently paid (0.142 RMB/m^3) by participants in Xi'an city. The results also identified a range of factors affecting farmers' WTP. While participants were aware of a growing water deficit, few participants believed that the water deficit was a problem that directly impacted their farm operation.

Nonetheless, a higher awareness seemed to predict an increases in participants' WTP for irrigation water. This finding highlights the significance of continued outreach by the extension service to increase awareness of the water crisis in northwest China. In total, 6 variables have a positively statistically significant impacts on WTP, including years of farming, gross income, percent farm income, irrigation water shortage, farmers' views on current water price and awareness of water price reform. In contrast, the bidding, age, and total hectares had negative and statistically significant impacts on producers' WTP. A somewhat unexpected results was that farmer' WTP decreased if they chose to use water saving technology, which may have important policy implication in sustainable management of water resources as shown in the following.

This paper demonstrated how water pricing in the agricultural sector based on farmers' WTP can be derived to evaluate agricultural water management strategies that involve water allocation policies, conservation options, and irrigation practices.

5.2. Policy implications

In the context of climate change and the transformation of traditional economic development, water price increases have been implemented by the Chinese government aiming to achieve sustainable utilization of agricultural water resources. The rationality of the water price directly influences farmers' responses to water price reform, their irrigation decision behavior, and their motivation for conservation. Farmers are the main bearers of water prices, and farmers' income and agricultural income are relatively low. In this case, if increasing the water price does not consider farmers' tolerance or the water price is much higher than the maximum wiliness to pay, then the water pricing policies cannot truly be among the most effective tool for managing water resources, and the goals of the water price reform will not be achieved in China. Therefore, it is of great practical significance to quantitatively analyse the optimal range of agricultural water price adjustment from farmers' behaviour, demand and willingness. According to the results obtained in this paper, the following policy implications are presented. First, the government should grasp the scale of the water price adjustment. For example, the government should implement differential water prices in different areas based on socio-economic status and geographic position. From our study, in the Yanta district farmers' WTP is higher than the current price while in Zhouzhi county the WTP is much lower than the price currently paid. Thus, water price can be appropriately increased in areas with better economic conditions to increase water use efficiency. However, in economically under-developed areas, the government should design relevant subsidy policies to compensate for the negative impact of increasing water price on farmers. Second, the government should take correct guidance responsibility for the water scarcity and steer farmer consciousness and behaviour in the correct direction. For example, farmers who had a higher awareness of water price reform and considered water resource scarce were more likely to have higher WTP. Many people believe that water is a public resource and inexhaustible. In addition, the low WTP also influenced by the traditional concept that irrigation is the responsibility of the state and should not be undertaken by farmers. Therefore, the government has the responsibility to increase farmers' awareness of the water crisis. Third, the government must strengthen water conservation and consumption education for young people. For example, our results showed that there were significant differences in age in terms of the WTP; younger less than 48 years of age had a higher WTP than those participants older than 48 years (Fig. 3). This result was mainly because younger people have more knowledge regarding water resources, frequent access to water crisis education, have a higher education. As future citizens of our society, young people will join our world and become a major force in water conservation and realizing the value of water in the near future.

Nevertheless, the conclusion that the participants who chose to use water saving technology decreased the WTP could have important implications in the theory and practice of sustainability. While large water savings or a water use efficiency increases could be achieved by increasing participants' awareness of using water-conservation technology, such practices may also decrease the level of the farmers' WTP for water from irrigation districts. If the decreasing influence on the WTPs of adopted water saving technology was to the extent that the government cannot set the price of the water to a level that allowed them to recover the cost of the investment in equipment, then the financial viability of the practices may be hampered. A similar conflict may also arise between conservation programmes that focus on improving irrigation efficiency and programmes that focus on conversions to drip or sprinkling irrigation methods. Both types of programmes would positively impact the sustainability of the water demand management by reducing water usage. However, the effectiveness of the viability of the practice may negatively influence the other water saving programme. If such changes limit the revenue earned by irrigation districts, the financial viability of such practices may also be limited. Therefore, policymakers need to consider such unintended consequences when promoting water-saving technology. For example, water-saving technology implementation that focuses on improving water use efficiency may be more beneficial in areas where the government invested in these water-saving facilities and infrastructure.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jclepro.2019.06.269.

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