Can Internet Access Increase Agricultural Labor Productivity? Micro Evidence from China*

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Abstract

To examine the effect of the internet on agricultural labor productivity, we implement the most extensive household survey of irrigation arrangements ever conducted in rural China. We also exploit a public program aimed at improving the quality of distance education in rural middle schools, which has led to plausibly exogenous variation in internet access across rural districts. We present a conceptual framework that highlights the transmission mechanisms whereby internet access may affect the selection of irrigation systems, and identify both a direct effect through agricultural production and an indirect effect through service production. We find evidence to suggest that internet access can effectively reduce information frictions and searching costs in the service labor market, thus increasing the participation of rural households in service production. To save more hours from agricultural production, rural households select less labor-intensive irrigation systems and thus obtain the higher agricultural labor productivity. Also, collective actions play an essential role in the choice of the irrigation system. Our findings have important implications for the ongoing policy debate over government investment in internet infrastructure to encourage labor productivity in rural and isolated areas.

Keywords: Internet, Irrigation, Labor Productivity, Information Frictions.
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1 Introduction

Does the internet affect the labor productivity and modes of production? Certainly, the internet has enabled new forms of information transmission, through online forums, instant messaging, and social networking. Meanwhile, economists and policymakers are very interested in understanding the effect of the internet on the economy. On the one hand, the internet enhances economic efficiency, for example by making markets more competitive, stimulating economic growth, and increasing wages [1] On the other hand, a growing number of economists and policymakers have started to emphasize the downside of the internet, such as loss of ideological segregation and increase in crime.[2]

To date, most of the research on the productivity effects of the internet has focused on the manufacturing and service sectors.[3] There have been very few studies on the productivity-enhancing effects of the internet in the agricultural sector, mainly due to the scarcity of objective data. In this paper, we present the first empirical evidence on the impact of internet access on agricultural production and irrigation arrangements.

To examine how internet access affects the production mode and the selection of irrigation types, we implement the most extensive household survey of irrigation arrangements ever conducted in rural China. By collecting information on agricultural production and living conditions for a high quality, nationally representative, sample of Chinese rural residents, the survey aims to serve the needs of research in the rural and isolated areas in China. We find suggestive evidence that internet access can effectively reduce information frictions and searching costs in the service labor market, thus increasing the participation of rural households in service production. To save more hours from agricul-

[1]See Brown and Goolsbee (2002), Czernich et al. (2011), Forman et al. (2012).

[2]Gentzkow and Shapiro (2011) suggest that ideological segregation on the internet is significantly lower in online interaction than in face-to-face interactions via social networks. Bhuller et al. (2013) state that internet use is associated with a substantial increase in both reports, charges, and convictions for rapes and other sex crimes.

[3]Akerman et al. (2015) suggest that the role of the internet is skill-biased. In other words, internet adoption complements skilled workers in executing non-routine abstract tasks, and substitutes for unskilled workers in performing routine tasks. Bloom et al. (2015) conducted a working-from-home experiment at a Chinese travel agency and found that home working led to a 13% performance increase.

tural production, rural households select less labor-intensive irrigation systems and thus obtain the higher agricultural labor productivity (we use productivity for short hereafter).

We begin by presenting a conceptual framework that highlights the transmission mechanisms whereby internet access may affect the selection of less labor-intensive irrigation systems. This indicates both a direct effect through agricultural production, and an indirect effect through service production. The direct effect on working hours is positive. Internet access can considerably reduce the information frictions in the job market, so that farmers with internet coverage more easily find part-time or service jobs. Consequently, they will spend more working hours in the service sector and reduce their labor input in the agricultural sector. The indirect effect on working hours is negative. The internet access could considerably reduce the information frictions in the job market; farmers with internet coverage would be more convenient to find part-time or service jobs. Thus, they spend more working hours in the service sector and reduce their labor input in the agricultural sector. Therefore, the net effect of internet on hour allocation in agricultural production is determined by which effect is dominant: the direct or the indirect.

We then estimate the net impact of internet access on the selection of irrigation types. Irrigation is a prominent factor in agriculture, where the selection of the irrigation system may be reflected in agricultural productivity. Different irrigation types involve different technology and thus required different amounts of capital as well as the labor input. Generally, the adoption of less labor-intensive irrigation systems leads to higher productivity. Conditional on province fixed effects and a full set of control variables, we use the ordered probit model and find that households with the internet access are more likely than those without the internet access to choose less labor-intensive irrigation types. In other words, internet increases the agricultural productivity in China.

To deal with the potential endogeneity problem regarding internet access, we exploit a public program introduced by the Chinese government in the 2000s, which aimed at ensuring internet access throughout rural China. We instrument the internet access of households by the distance from their village to the closest middle school. The rural middle school distance education program invested heavily in the construction of the internet stations and communication towers around the rural middle schools. Since households are much more likely to have internet access when their villages are closer to the internet stations and communication towers, thus we expect that internet access is negatively correlated with the distance to the nearest middle school. The two stage least square results show that our baseline results are robust and the potential endogeneity problem is not a serious concern.

In addition, we explore several possible transmission channels through which internet access leads to enhanced productivity. First, we check the different types of internet uses across households. Our results show that using the internet to search for information is both statistically and economically significant for choice of irrigation type, while use for shopping, social purposes, and entertainment are all insignificant. This indicates that internet access improves irrigation system productivity mainly through the acquisition of information. Second, we also find that trust and collective actions among households play essential roles. Collective action with regard to irrigation arrangements is based on cooperation among farmers; for example in the joint construction and maintenance of canals under customary rules, and the establishment of shared norms in rural communities or water user associations (WUAs) to restrict open access privately (Ostrom, 1990). We use self-reported satisfaction levels on five aspects (justice, approval, monitoring, feedback, and organization) to measure the extent of the collective actions. Our findings show that internet access impacts the selection of production mode by affecting the trust and collective actions among households.

By incorporating the role of local government, we find that households with internet access are even more likely to choose the less labor-intensive irrigation systems when they are located in the villages where the government publishes a full range of information online. This amplification effect has several important public policy implications. Since the widespread diffusion of the internet, there have been numerous policies aimed at subsidizing Internet infrastructure in rural areas; for example, the rural middle school distance education program. Our results suggest that infrastructure growth has little impact without online publication of information by the local government. Yet, most infrastructure subsidies include little or no provision for online government disclosure. Moreover, we find internet access affects the productivity of agriculture through the indirect effect, suggesting that policies ensuring internet access at a reasonable price throughout the rural and isolated areas should be advocated to reduce the information frictions and searching costs in the service. Finally, the local government should encourage, support, and monitor farmers' collective actions on irrigation systems among the farmers to enhance productivity in the agricultural sector.

This paper is related to a considerable number of studies that have focused on the efficiency-enhancing effects of the internet. Brown and Goolsbee (2002) examined that whether internet access makes markets more competitive. Yi and Choi (2005) found that the internet improves productivity and reduces inflation. Czernich et al. (2011) identified a positive correlation between internet penetration and economic growth across OECD countries over time. Forman et al. (2012) found evidence that internet investments correlate with wage and employment growth in some but not all counties in the United States. Gaining access to internet services could substantially increase the employment rate, with more substantial effects in rural and isolated areas (Atasoy, 2013).

Our results showing that internet has a negative effect on labor allocation contributes to the literature on the downside of the internet. Gentzkow and Shapiro (2011) suggest that ideological segregation on the internet is significantly lower than the segregation of face-to-face interactions in social networks. Bhuller et al. (2013) state that internet use is associated with a substantial increase in both reports, charges, and convictions for rapes and other sex crimes.

Our article builds and extends on the literature on the productivity effects of the internet in agricultural sector, which compliment to internet effects in the manufacturing sector. According to Atasoy (2013), the correlation is more robust in counties where a larger share of the population holds a college degree, pointing to a skill complementarity of the internet. Akerman et al. (2015) suggest that the role of the internet is skill-biased; in other words, internet adoption complements skilled workers in executing non-routine abstract tasks, and substitutes for unskilled workers in performing routine tasks. Bloom et al. (2015) conducted a working-from-home experiment at a Chinese travel agency and found that home working led to a 13% performance increase. In this paper, we shall present the first empirical evidence on the impact of internet access on agricultural production and irrigation arrangements.

In addition, our paper explains the selection of irrigation system by a new channel, namely labor reallocation. This complements the traditional work on collective action based on cooperation among farmers, for example in joint construction and maintenance of canals under customary rules, and the establishment of shared norms in rural communities or water user associations (WUAs) to restrict open access privately (Ostrom, 1990; Tang, 1992; Suhardiman and Giordano, 2014). Several papers deal with the effect of information diffusion on collective action (Huang and Sun, 2014; Pierskalla and Hollenbach, 2013; Talhelm et al., 2014).

The rest of this article proceeds as follows. Section 2 presents a conceptual framework to help structure our discussion of the transmission mechanisms between internet access and less labor-intensive agricultural production. In Section 3 we describe our data and variables, while in Section 4 we discuss our empirical strategy. Main findings are reported in Section 5. Section 6 investigates the mechanisms through which internet access may affect the labor demand of the irrigation system, guided by our conceptual framework. In Section 7 we discuss the results from several robustness checks. Finally, Section 8 provides a summary of the research, and presents the policy implications.

2 Conceptual Framework

The macroeconomic and development models typically use two factors of production, capital, and labor. However, the land is intrinsically different from capital because capital can be accumulated while land cannot. Although the contribution of land in manufactures is probably negligible and there is no harm in equating land to capital, this is not the case with agriculture.

Thus we employ the three-factor agricultural production function proposed by Echevarria (1998), $y_A = zn^{\alpha}k^{\beta}l_A^{\gamma}$, where y_A is the value-added in the agricultural sector, z is the total factor productivity, and n,k,l are land, capital, and labor used in the sector. y_A is produced with a constant return to scale technology: $\alpha + \beta + \gamma = 1$. For simplicity, capital k is only be considered as the capital input of the irrigation system.

2.1 Two-sector Production Model

We develop a two-sector production model with different production functions in various factors. Takayama et al. (2018) states that the number of non-farmers and part-time farmers increased with urbanization. In this model, there are two sectors: agricultural production sector A and service sector S. The service production is labor-dependent. Since this is the production function for the farmer as a part-time job, by no means to assume farmers have any incentive to put into any capital, thus we employ the single-factor production function in the service sector: $y_S = l_S^{\rho}$.

We normalize the capital price as one. Denote the price of agricultural goods as p_A and that of service output as p_S. Since land is fixed and exogenous given in this paper, the technology and contribution of the land could be captured by the price of the agricultural products p_A. The profit maximization problem could be written as

$$\max_{k,l_A,l_S} p_A k^{\beta} l_A^{\gamma} - k + p_S l_S^{\rho}. \tag{1}$$

According to Krusell et al. (2000), the labor input of each sector is measured in efficiency units: each input type is a product of the raw number of labor hours and an efficiency index: $l_A \equiv \psi_A h$ and $l_S \equiv \psi_S h_S$, where h_i is the number of hours worked and ψ_i is the quality per hour in sector i. Here ψ_A is interpreted as human capital, accumulated by the agent through the internet access. ψ_S is construed as the searching efficiency of finding a part-time job, which is improved by the information online.

Each farmer is endowed with a fixed total labor $\overline{h}$, and he or she could choose to spend their time in either the agricultural sector or service sector, that is $h + h_S = \overline{h}$. In this case, the farmer's optimization problem could be simplified to

$$\max_{k,h} p_A k^{\beta} (\psi_A h)^{\gamma} - k + p_S \psi_S^{\rho} (\overline{h} - h)^{\rho}. \tag{2}$$

The first-order conditions respect to the capital k and labor in the agricultural sector h could be written as

$$k : \beta p_A k^{\beta} (\psi_A h)^{\gamma} / k = 1, \tag{3}$$

$$h : \gamma p_A k^{\beta} (\psi_A h)^{\gamma} / h = p_S \psi_S^{\rho} \rho (\overline{h} - h)^{\rho}. \tag{4}$$

The equality that the marginal product of capital equals the marginal product of labor is given by

$$\frac{h}{(\overline{h} - h)^{1-\rho}} = \frac{\gamma}{\beta p_S \psi_S^{\rho} \rho} k. \tag{5}$$

Since most of the literature consent that the market in the service sector is perfectly competitive, in other words, individual farmers are all price-takers. Thus, we could simplify the calculation considerably by assuming that the production function in the service sector has a constant return to scale in labor input l_S, which is $\rho = 1$. Thus equation (5) could be simplified as

$$h = \frac{\gamma}{\beta} \frac{1}{p_S \psi_S} k. \tag{6}$$

We could now link equation (3) and (6) as follows:

$$k^{1-\beta-\gamma} = \beta^{1-\gamma}\gamma^{\gamma}\left(\frac{\psi_A}{\psi_S}\right)^{\gamma}\frac{p_A}{p_S^{\gamma}}. \tag{7}$$

2.2 The Effect of the Internet

To facilitate drawing a connection between our analysis and the literature, we assume the internet access could improve the efficiency index in both the agricultural sector and service sector, ψ_A, and ψ_S. These efficiency factor variables are assumed to be unobserved by the econometricians.

The capital in this specification is driven entirely by two factors: the direct relative quantity effect and the indirect agriculture-service substitution effect. The impact of capital result from the change of ψ_A is considered as direct effect because capital and agricultural labor interact with each other in the production function directly. The impact generated by the shift of ψ_S is regarded as an indirect effect because service labor could not affect capital directly (they are in different sectors).

To see how internet access may affect the labor allocation between the agricultural and service sectors, we take the partial derivative of equation (6) with respect to efficiency coefficients ψ_A and ψ_S.

$$\frac{\partial \ln h}{\partial \ln \psi_A} = \underbrace{\frac{\gamma}{1-\beta-\gamma}}_{\text{direct effect}} > 0. \tag{8}$$

Since $1-\beta-\gamma = \alpha > 0$, the direct effect to hours is positive. The intuition is quite obvious. When the labor efficiency in agriculture increases, farmers would have more incentives to increase their working hours in agricultural production.

$$\frac{\partial \ln h}{\partial \ln \psi_S} = \underbrace{-\frac{1-\beta}{1-\beta-\gamma}}_{\text{indirect effect}} < 0. \tag{9}$$

The indirect effect on working hours is negative. The internet access could considerably reduce the information frictions in the job market; farmers with internet coverage would be more convenient to find part-time or service jobs. Thus, they will spend more working hours in the service sector and reduce their labor input in the agricultural sector.[4]

Moreover, to see how internet access may affect capital (irrigation system), we take the partial derivative of equation (7) with respect to efficiency index for agricultural production ψ_A and service production ψ_S.

$$\frac{\partial \ln k}{\partial \ln \psi_A} = \underbrace{\frac{\gamma}{1-\beta-\gamma}}_{\text{direct effect}} > 0. \tag{10}$$

The direct effect of capital is positive because the rise in labor (direct effect) would increase the marginal product to capital and more capital are used as a result.

$$\frac{\partial \ln k}{\partial \ln \psi_S} = \underbrace{-\frac{\gamma}{1-\beta-\gamma}}_{\text{indirect effect}} < 0. \tag{11}$$

Finally, the indirect effect on capital is negative because the reduction in labor (indirect effect) would decrease the marginal product to capital.

2.3 Linking the Channels Together

We can now link the direct channel and indirect channel together. The effect of efficiency shock on working hours in the agricultural sector could be written as

$$\begin{aligned} dh &= \frac{\partial h}{\partial \psi_A} d\psi_A + \frac{\partial h}{\partial \psi_S} d\psi_S \\ &= \frac{1}{1-\beta-\gamma}[\underbrace{\gamma\frac{d\psi_A}{\psi_A}}_{\text{direct effect}} \underbrace{-(1-\beta)\frac{d\psi_S}{\psi_S}}_{\text{indirect effect}}]h. \end{aligned} \tag{12}$$

[4] Forman et al. (2012) suggest the evidence that internet investments correlate with wage and employment growth in some but not all counties in the United States. Gaining access to internet services could substantially increase the employment rate, with more substantial effects in rural and isolated areas (Atasoy, 2013).

Proposition 1. *If the direct effect exceeds the indirect effect i.e.,* $\frac{d\psi_A}{\psi_A} > \frac{1-\beta}{\gamma}\frac{d\psi_S}{\psi}$*, then working hours in agricultural production* h *will increase with the positive shock of internet on both* ψ_A *and* ψ_S *, and verse versa.*

Proof. Given $\frac{d\psi_A}{\psi_A} > \frac{1-\beta}{\gamma}\frac{d\psi_S}{\psi}$, that is $\gamma\frac{d\psi_A}{\psi_A} - (1-\beta)\frac{d\psi_S}{\psi_S} > 0$, we have

$$dh = \frac{1}{1-\beta-\gamma}[\gamma\frac{d\psi_A}{\psi_A} - (1-\beta)\frac{d\psi_S}{\psi_S}]h > 0. \qquad \blacksquare$$

Similarly, the effect of efficiency shock on capital in the agricultural sector could be represented as

$$\begin{aligned} dk &= \frac{\partial k}{\partial \psi_A}d\psi_A + \frac{\partial k}{\partial \psi_S}d\psi_S \\ &= \frac{\gamma}{1-\beta-\gamma}[\underbrace{\frac{d\psi_A}{\psi_A}}_{\text{direct effect}} \underbrace{-\frac{d\psi_S}{\psi_S}}_{\text{indirect effect}}]k. \end{aligned} \tag{13}$$

Proposition 2. *If the direct effect exceeds the indirect effect i.e.,* $\frac{d\psi_A}{\psi_A} > \frac{d\psi_S}{\psi_S}$*, then capital* k *will increase with the positive shock of internet on both* ψ_A *and* ψ_S*, and verse versa.*

Proof. Given $\frac{d\psi_A}{\psi_A} > \frac{d\psi_S}{\psi_S}$, that is $\frac{d\psi_A}{\psi_A} - \frac{d\psi_S}{\psi_S} > 0$, we have

$$dk = \frac{\gamma}{1-\beta-\gamma}[\frac{d\psi_A}{\psi_A} - \frac{d\psi_S}{\psi_S}]k > 0. \qquad \blacksquare$$

Equation (13) highlights that the net impact of internet access on the selection of irrigation systems consists of three distinct components. The first term is the direct effect coming from the improvement of the efficiency to agricultural labors, and the second term represents the indirect effect leading by the increase of the effectiveness of service labors.

3 Data and Variables

3.1 Data

In this study, we employ the confidential data gathered through a household survey conducted by the China Institute for Rural Studies (CIRS) at Tsinghua University. We implement the most extensive household survey of irrigation arrangements ever done in rural China. This household survey aims to collect information on agricultural production and living conditions for a high quality, nationally representative, sample of Chinese rural residents to serve the needs of scientific research in the rural areas in China.

Our unit of analysis is the rural household. this is the smallest social unit in rural villages, where production is conducted in household units in China. The survey data adopts multi-stage stratified PPS sampling. Around a thousand investigators were trained by the experts at the China Institute for Rural Studies (CIRS). Fieldwork was carried out in 2015, and data were collected from 5730 households in 23 provinces and 569 villages. To our knowledge, our data represent the most comprehensive information regarding the irrigation at both the village and household levels.

To reduce the measurement error, we winsorize all variables at the 1% and 99% levels to lessen the influence of outliers. Furthermore, to address the concern of the small sample bias, all of the villages with fewer than ten household questionnaires returned were dropped from our sample. Therefore, our analysis is based on a random sample of 3757 households located across 23 provinces in China. Compared with most of the existing literature in this area, our sample is much larger and more complete.

3.2 Dependent Variables: Irrigation Systems

Irrigation is a prominent factor in agriculture. The main goal of irrigation is to match precisely the water demand of the crops with the water supply from the farmers across different growth stages. More specifically, the farmers should provide less water during the growth stage, and more water during the fruiting stage.

Irrigation systems are common-pool resources and have been utilized in the existing literature as a typical case for analyzing collective action. Given the nature of irrigation systems, where it is difficult to exclude particular users, the free-rider problem is widespread. Collective action for irrigation arrangements is based on cooperation among farmers, for example through joint construction and maintenance of canals under customary rules, and the establishment of shared norms in rural communities or water user associations (WUAs) to restrict open access privately (Ostrom, 1990; Tang, 1992; Suhardiman and Giordano, 2014). Such collective actions face challenges in terms of organizing resource users, monitoring, and enforcing the rules. A number of studies have investigated the determinants of the success for the management of irrigation systems. (Dayton-Johnson, 2000; Meinzen-Dick et al., 2002; Nagrah et al., 2016) We will discuss the collective action of the irrigation system in more detail in Section 6.3.

This paper assigns an ordered dummy variable for different types of irrigation arrangements, where 3 is the highest score, and assigned to canal irrigation; 2 is assigned to well irrigation, 1 to lift irrigation, and 0 to relying on no irrigation. This ranking is based on a direct indicator of irrigation productivity, where productivity is highest for canal irrigation, since it saves the most significant amount of labors. Well irrigation has a lower level of productivity, due to the need for more labor. Lift irrigation is even more labor-intensive, because it relies entirly on the power of humans and livestock. No irrigation system at all is the most labor-intensive case, as explained below.

First and foremost, households without any irrigation system need to work very hard during the drought period. Sometimes all the crops may die because of the water shortage, which means that all the previous labor inputs are wasted.

Secondly, Households without the irrigation system have to grow the crops with higher tolerance to drought than those grown by their neighbors who do have irrigation systems in the same village. Since the agricultural goods market in China is perfectly competitive, such drought-tolerant crops need more labors in other aspects, such as ploughing the soil, manuring, and weeding.

Thirdly, some households choose not to have an irrigation system because they do not grow on the same land every year. Given China's high population, especially among farming communities, the shortage of land is a significant problem, and there may not be enough land for every household to cultivate. Villages deal with this problem by giving the families permission to cultivate land for one year in every two or three years. Furthermore, the share of outward migration is extremely high in rural areas (Wang et al., 2016), and a farmer may choose not to continue to cultivating the land if he is able to find a suitable job in a city. In this case, the households would have no incentives to construct or maintain any irrigation system; instead, they would pay for a water team or buy water from the families that do have irrigation systems. In either case, given the efficient market, they would have to pay more compared with those families that possess an irrigation system.

Fourthly, the main goal of irrigation is to keep the water supply equals the water demand. If this goal couldn't be attained, the households without the irrigation system need to put into more labors in other aspects to gain similar outcomes as their neighbors in the same village; for example they will need to weed more or turn the soil more.

Lastly, 3.6% of the households in our sample state that they have to use the tap water to irrigate during the drought periods, to make up for the absence of an irrigation system. Tap water is very costly, and this practice represents a waste of labor.

The ranking outlined above is somewhat subtle and indirect. However, a distinct advantage of this form of measurement is that only the more objective or observable data regarding the irrigation types needs to be taken into consideration. Unlike workers in the manufacturing sector, most of the farmers in China work only for themselves, and it is impossible to observe their exact labor input, while the ex-ante self-reported working hours may not be accurate, and may suffer from the measurement error.

3.3 Independent Variables: Village-level Factors

We consider two types of control variables. The first type comprises unobserved determinants of irrigation type that are fixed at the village level, which we control for through the village indicators. To identify factors that are likely to correlate with the irrigation types, we relied on the existing literature on physical attributes, community attributes, and institutional contexts.

3.3.1 Physical Attributes

Physical attributes comprise three variables: topography, location, and water scarcity. We use these three variables to control for geographic heterogeneity that may be correlated with the choice of irrigation type. Topography is a dummy variable where the value 1 is assigned to plains, and 0 is assigned to hilly or mountainous areas. The cost of construction and maintenance of the irrigation system should be higher in hilly or mountainous regions. For example, there would be particular difficulties involved in digging canals through mountains and hills. Moreover, increasing return to scales is more likely to be realized for an extensive irrigation system located on a plain than in the hills or mountains.

The distance to market town has been widely recognized as a determinant factor for productivity irrigation arrangements (Meinzen-Dick et al., 2002; Takayama et al., 2018). Villages closer to markets are likely to be more commercially oriented, and therefore have higher payoffs to adequate irrigation. In this article, because we were not able to observe the exact distance to market towns, we use another alternative variable to measure the proximity to markets. Location is a dummy variable equal to 1 if the village is non-suburban and 0 otherwise.

According to Araral Jr (2009), water scarcity has a quadratic effect on irrigation arrangements; that is, cooperation is more difficult when water is abundant (there is little incentive to cooperate since water is plentiful) and when water is extremely scarce (there is potential conflict over water allocation). Most of the existing literature agrees that farmers are more willing to construct and manage more effective irrigation systems when water is neither extremely abundant nor extremely scarce, but is only moderately scarce. In this paper, moderate water scarcity is a dummy variable for 1 indicating moderate water scarcity and 0 otherwise. In addition, we also use severe water scarcity (an indicator variable with a value equal to 1 where there is severe water scarcity and 0 otherwise) to control for the heterogeneous effect of irrigation arrangements among extremely scarce water supply and other situations.

3.3.2 Community Attributes

We use three variables to measure the heterogeneous socioeconomic effects at the community level: village size, income inequality, and labor migration. First of all, according to Poteete and Ostrom (2004), group size appears to have a non-linear relationship to at least some forms of arrangements; this is because of a trade-off between potential economies of scale and increased transaction costs. Village size is measured by the log of the number of households in the specific village.

Second, existing literature suggests that homogeneous communities, especially those with income and wealth homogeneity, might find it relatively easy to make decisions collectively (Agrawal and Gibson, 1999; Khalkheili and Zamani, 2009). Income inequality is measured by the Gini index calculated base on household income for the specific village. We use the village-level Gini index instead of household-level income to avoid the reverse causality problem brought by adding the variable income directly.

Third, Wang et al. (2016) find that migration has a statistically significant adverse effect on collective irrigation. Migration leads farmers to place greater value on the service-related jobs in urban areas than on agriculture-related work in rural areas. In our study, labor migration is measured by the percentage of households with out-migrants over the total number of households at the village level.

3.3.3 Institutional Context

Over the last four decades, the Chinese government has been continually improving the effectiveness of irrigation to increase productivity in rural areas. Many of the characteristics of the resources and behaviors of resource users are mediated by institutional contexts such as the cost of monitoring and rule enforcement (Stern et al., 2002). In this research, institutional contexts comprise two aspects: governance failure, and monitoring and sanctioning rules. Governance failure is an indicator variable with a value of 1 for villages that have petitioned over land circulation in the previous three years, and 0 otherwise. The local government should monitor land circulation, and the presence of petition indicates its failure in this regard. The failure of governance may damage the trust and cooperation among the farmers.

Monitoring and sanctioning rules is an indicator variable with a value of 1 where sanctions have been imposed against the free-rider problem (e.g., cutting channels privately or evading irrigation fees), and 0 otherwise. The free-rider problem would damage the effectiveness of the irrigation systems and should be monitored by the local government.

3.4 Independent Variables: Household-level Factors

The second type of independent variable comprises the unobserved factors at the household level, which we control for through the household variables, Z_h. First of all, according to the findings of Khalkheili and Zamani (2009), crowded families have more labor and thus have greater opportunity to participate in irrigation arrangements. The share of labor is measured by the percentage of labors over the number of family members in a specific household.

Secondly, following previous literature on irrigation arrangements, we consider the distance to the irrigation system. There are empirical evidences that households with an around average distance to an irrigation system have the highest incentives to construct and maintain that system compared with the households located further away (lower benefits), and those nearby (easy to get). Moderate distance to irrigation is a dummy variable equal to 1 where there is moderate distance to the irrigation system and 0 otherwise. In addition, to control for the alternative situations, we include long distance to irrigation (with 1 indicating the long distance to the irrigation system and 0 otherwise).

Thirdly, past irrigation shortage may affect household irrigation decision making. In this study, past irrigation shortage is an integral value where 1, 2, 3, 4, and 5 representing never, seldom, sometimes, often, and always, respectively.

Fourthly, the impact of insufficient irrigation is a dummy variable with a value of 1 indicating adverse impact and 0 otherwise. This factor emphasizes the role of the households' memory. Households with bad memories regarding insufficient irrigation have more incentive to acquire more reliable and effective irrigation systems in the future.

Finally, we also considered some other household attributes that may be correlated with both irrigation arrangements and internet access, such as the age and education level of the household head. Most of the existing literature suggests that the effects of age and education level on irrigation arrangements are complex and conditional on the specific situation.

4 Empirical Strategy

4.1 Ordered Probit Model

Since the potential values of the dependent variable have a natural ordering, we use the ordered probit model to analyze the corresponding probability. To estimate the effect of internet access on the selection of the irrigation system, we employ the ordered probit model with the following regression:

$$y_{vh} = \beta_0 + \beta_1 Internet\ Access_{vh} + \beta_2 X_v + \beta_3 C_h + \lambda_p + \epsilon_{vh} \tag{14}$$

where the dependent variable y_{vh} is the types of irrigation systems used by household h in village v, $Internet\ Access_{vh}$ is the availability of internet for household h in village v, X_v is a full set of village-level variables to control for the heterogeneous effects at the village level, C_h is a full set of variables to control for the heterogeneous effects at the household level, the relevant description of all the variables are in Section 3.2, and they are also summarized in Table 1.

To avoid the omitted variable problem, we include the province fixed effect, λ_p, to address for the heterogeneous effects at the province level, such as climate, culture, water condition, and irrigation policy in specific areas. To address the concern regarding interdependence at the village level, throughout the paper all standard errors in this paper are clustered at the village level, and are robust to heteroskedasticity.

We also employ the alternative measurements of the irrigation arrangements as well as the internet access to reduce the measurement error in the robustness check section, and the results show that our estimated effects are remarkably robust to all the checks performed in the empirical studies.

4.2 Instrumental Model

In September 2003, the Chinese central government began a program of expansion of services related to information and communication technology into all rural middle schools in China, especially those located in the poor and isolated areas. The main goal of the rural middle school distance education program was to ensure that every middle school throughout the rural areas in China had access to distance education, which would reduce the education inequality between urban and rural areas.

To achieve these goals, the Chinese government spent a total of 11.1 billion yuan, 5 billion of which came from the central government and 6.1 billion from the local government. Most significantly, it invested heavily in the hardware facilities. By the end of 2007, around 37,500 rural middle schools across China had computer rooms set up with the support of the program. In addition, all the middle schools were required to ensure access to the internet. With these facilities in place, the program is dedicated to linking the information and communication technology with the school curricula.

We instrument the internet access of households by the distance from their village to the closest middle school. Because the rural middle school distance education program invested heavily in the construction of the internet stations and communication towers around the rural middle schools. Since households in villages closer to those facilities can access the internet more easily, we expect that internet access is negatively correlated with the distance to the nearest middle school. On the other hand, because the location of the middle school is decided by the Ministry of Education, which is independent of the Ministry of Agriculture, we expect that there is no correlation between the nearest middle school and the unobserved determinants of irrigation type.

For each household, we instrument $Internet\ Access_{vh}$ with $Dist_v$, the (log) distance form the village to the nearest middle school. The two-stage least square model is given by the following two-equation system, where (16) is the first stage and (15) is the second stage:

$$y_{vh} = \beta_0 + \beta_1 Internet\ Access_{vh} + \beta_2 X_v + \beta_3 C_h + \lambda_p + \epsilon_{vh} \quad (15)$$

$$Internet\ Access_{vh} = \beta_0' + \beta_1' Dist_v + \beta_2' X_v + \beta_3' Z_h + \lambda_p' + \epsilon_{vh}' \quad (16)$$

In all cases, the subscript v denotes village, and the subscript h means household. y_{vh} is the types of irrigation systems, $Internet\ Access_{vh}$ is the availability of internet for the specific household, X_v is a full set of control variables at the village level. At the same time, C_h is a complete set of control variables at the household level, all the detailed descriptions of the variables are described in Section 3.2 and summarized in Table 1. All standard errors are clustered at the village level and robust to heteroskedasticity.

5 Net Effect of Internet Access on the Selection of Irrigation System

This section begins by providing summary statistics for the key variables. Next, we illustrate the baseline results of our ordered probit estimation. We then consider the results from the IV estimates. Finally, we distinguish direct effects from indirect effects and discuss which of these two is dominant.

5.1 Descriptive Statistics

Table 2 displays summary statistics for the key variables. Descriptions of each of the variables are given in Table 1. At the village level, Table 2 shows that approximately 27.0% of the sample households have access to the internet. The average Gini index at the village level is 0.412, while the share of households with out-migrants over total households at the village level is 40.7% on average. Moreover, 29.9% of the villages are located in plain areas, 82.1% are non-suburban villages, and water shortage is modest and severe in around 31.7% and 30.9% of villages, respectively. Approximately 76.8% of villages have presented petitions or experienced conflicts in the last three years, and 23.4% of villages impose rules against free riders.

At the household level, Table 2 indicates that, on average, the percentage of labor in the household is about 48.6%. With regard to distance to irrigation system, around 36.9%, and 11.1% of households hold the farmlands that are at moderate or long distance, respectively. Approximately 42.1% of households have experienced insufficient irrigation. Around 49.7% of households are adversely affected by the shortage of irrigation. The descriptive statistics of household attributes in our household survey data are very close to the statistics in prior studies of rural China: the average age of the household head is nearly 47, and there are around 55.9% of household heads finished their junior high school.

Table 3 displays the distribution of irrigation types by different groups. The households with internet access have a much higher propensity to use irrigation systems, especially canal irrigation. We also find some impressive results for the determining factors of the irrigation system at both the village and household levels. The results show that villages located in plain areas have more incentives to use the irrigation systems, especially well and canal irrigation.

In addition, Table 3 shows that villages located in suburban areas are more likely to employ irrigation systems, especially canal irrigation. Villages with moderate water scarcity strongly prefer the lift and well irrigation, while villages with severe water scarcity choose to produce without any irrigation system. Villages that have not suffered from governance failure show a preference for well and canal irrigation. Finally, the villages with monitoring and sanctioning rules have a much higher propensity to choose canal irrigation.

We also find some interesting relationships at the household level. Table 3 indicates that households with relatively high education levels are more likely to use irrigation systems, especially canal irrigation. Households that have experienced irrigation shortage in the past are less likely to use any irrigation system. Households influenced by the adverse impact of insufficient irrigation have a strong preference to employ an irrigation system. Finally, households at a moderate distance to irrigation are more likely to use the irrigation system. However, households at a long distance to irrigation have a much lower propensity to select canal irrigation.

5.2 Baseline Results

Table 4 reports results from the ordered probit model given by equation (14). Column 1 presents the estimates from the specification with only the main set of the control variables and without the province fixed effect. The coefficient of internet access is 0.113 and significant, which implies that households with the internet access are more likely to to choose less labor-intensive irrigation types compared with the households without internet access. Columns 2-4 in Table 4 include province fixed effect and more control variables to check to what extent the ordered probit estimates of internet use on irrigation types are sensitive. We first add province fixed effect in column 2, not only the effect of internet access on the selection of irrigation types increases from 0.113 to 0.145, but also it becomes more substantial (significant at 5% level). Another potential threat to our estimation is the effect of the long distance to the irrigation system. To address this concern, column 3 in Table 4 adds the long distance to irrigation as a control. Again, we find that the estimated effects are quite similar; the inclusion of the long distance control indicates that the positive impact of internet access on irrigation types is substantially more significant (It increases from 0.145 to 0.182, and becomes significant at 1% level.). A further worry is that the condition of severe water scarcity may be correlated with the optimization of irrigation type. It is therefore reassuring to see in column 4 that our estimates barely move when we control for the condition of the severe water scarcity.

Table 4 also reports the effect on irrigation arrangements of four aspects of the control variables. From now on, we refer only to the results in column 4, because these relate to the specification with a full set of control variables and province fixed effects. First of all, for the variables related to physical attributes, the villages located in plains are more likely to choose a more effective irrigation system compared with villages located in hills or mountains. Furthermore, distance to the market is positively correlated with the effectiveness of the irrigation system. Canal irrigation systems are less likely to be chosen when water is abundant or extremely scarce. With regard to community attributes, income inequality as measured by the Gini index is negatively correlated with the effectiveness of the irrigation system, while the village size is significantly positively correlated with the productivity of agricultural production. Labor migration has a positive effect on choice of irrigation type, but not significantly so. Concerning the impacts of institutional factors, we find that the petitions and conflicts in the last three years have a significantly negative effect on irrigation productivity. Finally, villages that impose rules against free riders are more likely to choose less labor-intensive irrigation types.

With regard to the control variables specifically related to the household attributes, as can be seen from column 4 of Table 4, a higher percentage of labors over the number of family members is associated with a higher probability of choice of modern irrigation system. Households with an older or more educated household head are more likely to select a less labor-intensive irrigation system. Past experience of irrigation shortage experience has a significantly negative impact on the household irrigation decision. Moreover, households that have experienced harmful effects of insufficient irrigation are more willing to select less labor-intensive irrigation systems. Surprisingly, our findings show that households at both moderate and long distances from the irrigation system are more likely to choose an effective irrigation system, which is consistent with the results in Wang et al. (2016).

5.3 IV Results

Table 5 reports the results from the IV model given by equations (15) and (16). The first stage instruments the distance to the closest high school, and the first stage coefficient of internet access is about -0.05. This result implies that households closed to high schools are more likely to have access to the internet, and this effect is very significant. The first-stage is strong, with an F-statistic around 42, which means that weak instrument bias is not a concern.

Turning to the second stage results, as reported in column 1 of Table 5, households with internet coverage are more likely to choose the less labor-intensive irrigation types. Columns 2-4 in Table 5 include province fixed effects and additional control variables to see to what extent the IV estimates of internet access on irrigation systems are sensitive to the inclusion of heterogeneous effects at the province level and observable factors. We find that the estimated results are quite similar to those in column 1.

Overall, comparing these results with those of the ordered probit model, the inclusion of the IV estimation indicates that the positive effect of internet access on the selection of irrigation type is both statistically and economically more substantial.

5.4 Direct vs. Indirect Effect

Given the data we have, it is not feasible to observe the substitution effects between the agricultural sector and the service sector directly. However, we can observe the types of farmers: full-time farmers and part-time farmers. According to the conceptual framework in Section 2, there should be no indirect substitution effect for the sub-sample of the full-time farmers.

Therefore, in Table 6, we include both internet access and the interaction between internet access and full-time farmer. Full-time farmer is a dummy variable with a value of 1 indicating full-time farmer and 0 otherwise. The specification in column 4 of Table 6 includes both the province fixed effect and the full set of control variables. We find that, for part-time farmers, internet access is significantly associated with the selection of a less labor-intensive irrigation system. However, full-time farmers with internet access are less likely to pursue less labor-intensive irrigation systems compared with the part-time farmers with internet access.

These empirical results are consistent with our analysis of the conceptual framework in Section 2. The sub-sample of full-time farmers are only able to work in the agricultural sector, and it is impossible for them to switch to the service sector. Therefore, for this full-time group, only the direct effect exists. In our model, we suggest that the direct effect to capital is positive, which means that the households with internet users are more likely to increase their labor input in the agricultural sector; in other words, they have more incentive to choose more labor-intensive irrigation types. This impact is consistent with our coefficient estimates for the interaction term of internet access and full-time dummies, as reported in Table 6.

Both the ordered probit estimation in Table 4 and the IV estimation in Table 5 show that the net effect of internet access on the productivity of agricultural production is significantly positive. In other words, for part-time farmers the indirect effect outweighs the direct effect. Recall that the proposition 1 in Section 2 states that if the direct impact exceeds the indirect effect, then working hours in agricultural production will increase, with the positive shocks to the efficiency index in both the agricultural and service sectors. This means that the more labor-intensive production modes will be selected in the agricultural sector. That effect is the reverse of the case in our empirical analysis.

6 Mechanisms

This section explores the mechanisms highlighted in Section 2. It begins by analyzing the different types of internet use and their effects on agricultural production. Next, we take advantage of our survey data on self-reported satisfaction levels to help us interpret the collective actions regarding the irrigation system. Finally, we focus on the role of the government, especially in terms of online publication of information.

6.1 Information Frictions and Searching Costs

To learn more about how people use the internet, and how the different activities could affect the productivity of agricultural production, we focus on four types of internet use, as distinguished in our household survey: entertainment, shopping, social, and information.

First, entertainment is a dummy variable, with a value of 1 where people use the internet to entertain themselves (e.g., listening to music, watching movies, and playing online games), and 0 otherwise. Second, shopping is another dummy variable, with a value of 1 where the internet is used for shopping online, and 0 otherwise. Third, social use is an indicator variable, assigned a value of 1 where users make friends and communicate with relatives and friends online, and a value of 0 otherwise. Finally, information includes searching for new technology and crop varieties, emergency measures, and market and sales information.

The estimates for the four different types of internet uses are shown in Table 7. The results in column 4 of Table 7 take into account both the province fixed effect and the full set of control variables. We can see that entertainment, social use, and information searches through the internet are positively correlated with the productivity of the irrigation system. In contrast, shopping via the internet is negatively correlated with productivity. However, only the effect of information searching is both statistically and economically significant, which means that internet access improves the productivity of the irrigation system mainly through the acquisition of information.

The results in Table 7 are consistent with our conceptual framework in Section 2, where we assume that internet access affects agricultural productivity through the increasing of the efficiency index in both the agricultural and service sectors. Among the four types of internet use, information searching could increase the efficiency indices by reducing the information frictions and improving the information set.

Furthermore, we find no evidence of a significant relationship between social internet use and the productivity of irrigation systems, which means that socializing online with relatives and friends does not increase the efficiency index significantly. While there is also another possibility that the direct effects offset the indirect effects, so that the net effect of social internet use is not significantly different from 0 through the channel of social. Our results are consistent with the finding by Gentzkow and Shapiro (2011) that the internet dramatically reduces the cost of acquiring information from a wide range of sources.

6.2 The Role of Government in Information Diffusion

From Section 6.1, we know that internet access affects the productivity of agricultural production through information searching. In this part, we consider how internet access might interact with the government information disclosure.

To answer this question, table 8 reports the estimates of regression on both internet access and the interaction of internet access with online publication of government information. Government online disclosure is a dummy variable with a value of 1 where the local government issues information online, and 0 otherwise. As can be seen from column 1, for households located in villages where the government does not issue information online, there is no evidence that internet access has a significant effect on the selection of the less labor-intensive irrigation types. However, in villages where the government does publish information online, families with internet access are more likely to choose the less labor-intensive irrigation systems. To check to what extent the ordered probit estimation is sensitive to the inclusion of additional factors, columns 2-4 report the results when province fixed effects and more control variables are taken into account. In both cases, our estimates remain largely unchanged.

Our findings have important policy implications for the debate about the role of government in the expansion of less labor-intensive production methods. Our estimates in Table 8 suggest that, to enhance agricultural productivity, governments should issue information online. Guided by our conceptual framework in Section 2, the local governments should ensure online publication of more information regarding the government economic plan and the latest market information, for example, new programs, supported projects, and job vacancies. This strategy could improve the efficiency index in the service sector, and further influence the economy through the indirect channel outlined in Section 2.

In addition, guided by the analysis regarding trust and collective actions in Section 6.3, and by the results reported in Table 8, we suggest that the local governments should publish online disclose more information related to the rules and regulations, electoral system, revenue, and expenditure, as well as the policy decisions and approved process. This would increase farmers' satisfaction level with regard to fairness and equity, their degree of consent. Moreover, this strategy could encourage the farmers to join the official or spontaneously organized associations, for example, the Water User Associations (WUAs). Furthermore, the local governments could provide more detailed information about the construction and maintenance of the irrigation systems. This kind of strategy could improve satisfaction levels as to the governments' obligation of supervision, and provide feedback regarding the public irrigation systems.

6.3 Collective Actions regarding the Irrigation System

As illustrated in Section 6.1, use of the internet can reduce information frictions and searching costs. In this part, we discuss the role of collective actions in the irrigation system, looking particularly at the purpose of the collective actions in households' decision making, and the reasons why households would finally choose a less labor-intensive production mode given the reduction in information frictions and searching costs.

A growing body of literature suggests that the coordination and cooperation are required for the maintenance of the canal irrigation, whereas in the cases of well and lift irrigation, intensive coordination is relatively unimportant. Where there is no irrigation system in place, there is no need for cooperation. To measure the extent of the collective actions among the households, We use self-reported satisfaction levels on five aspects (justice, approval, monitoring, feedback, and organization) . To discuss the influence of the internet on the collective actions of the irrigation system, we explore its effect of the internet on the five self-reported satisfaction levels.

Table 9 presents the results of several regressions on these five measurements. First and foremost, column 1 reveals the effect of the internet on satisfaction with justice, using the ordered probit specification with province fixed effect and control variables at both village and household levels. Justice is a self-reported variable to reflect the extent of fairness and equity in the process of the irrigation system with 5 indicating 'very satisfied', 4 'satisfied', 3 'neutral', 2 'dissatisfied', and 1 'very dissatisfied'. As can be seen from column 1, internet access is associated with significantly higher satisfaction regarding the fairness and equity in the process of the irrigation system.

Secondly, column 2 presents the relationship between the internet and approval via the ordered probit model. Approval is also an integral variable that describes the extent to which the construction and maintenance of the irrigation system are approved by most of the farmers in the village. Here, 5 representing 'strongly agree', 4 'agree', 3 'neutral', 2 'disagree', and 1 'strongly disagree'. As can be seen from column 2, internet access has a significantly positive impact on the probability that the establishment and management of the irrigation system are approved by most of the farmers.

Thirdly, the results in column 3 are also from the ordered probit model, we discuss the effect of the internet on satisfaction with monitoring. Monitoring is a self-reported variable used to measure the effectiveness of the supervision by the village coordinating committee, where 5 indicates 'strongly agree', 4 'agree', 3 indicates a neutral opinion, 2 'disagree', and 1 'strongly disagree'. The estimates reported in column 3 indicate that households with internet access are more likely to agree that the supervision by the village is effective, compared with families without internet access.

Fourthly, column 4 uses the ordered probit model to reveal the relationship between the internet and farmers' satisfaction with feedback. Feedback is a self-reported value to measure whether the organizers of the irrigation system could provide positive feedback when the farmers have problems or suggestions regarding the irrigation system. Here 5 indicates that farmers are 'very satisfied' with the feedback, 4 indicates 'satisfied', 3 'neutral', 2 'dissatisfied', 1 'very dissatisfied', and 6 'not applicable'. From the results in column 4, we find that internet access is associated with significantly higher satisfaction with the feedback provided by the organizers of the irrigation system.

Lastly, the probit model is used in column 5 to understand the influence of the internet on farmers' involvement in any organization. Organization is a dummy variable where 1 indicates involvement in any organization, association, or cooperation, and 0 indicates the absence of any such involvement. The results presented in column 5 shows that households with internet access are more likely to have the experience of involvement in organizations or associations, or of cooperation.

In summary, we find that internet access can substantially increase the self-reported satisfaction with fairness and equity, the extent of consent by most of the farmers, satisfaction with supervision, satisfaction with feedback, and the probability of joining an organization. Given that trust and collective actions are required in the less labor-intensive irrigation systems, all of these five aspects could contribute to the selection of such systems. Therefore, we find that internet access affects the selection of production mode by affecting the trust and collective actions among the farmers in a village or several villages.

7 Robustness Analysis

We have seen that our estimates are robust to the inclusion of a wide range of controls and fixed effects. To further increase our confidence in the estimation, we now report results from additional specification checks.

7.1 Alternative Measurements of Irrigation Arrangements

Three alternative measurements of irrigation arrangements are widely used in the existing literature: 'contribution', 'maintenance', and 'meeting'. Table 10 reports the estimates based on these three alternative measurements. In column 2, we examine the effect of the internet on contribution to the maintenance of the irrigation system. This is an integral variable where 1 indicates no contribution, 2 indicates labor only, 3 capital only, and 4 both capital and labor. As can be seen from column 2, households with internet access are more likely to make greater contributions to the irrigation systems compared with the families without internet access. These estimates are very close to our baseline. Moreover, we discuss the effect of the internet on maintenance in column 3. Maintenance represents the frequency of participation in maintaining an irrigation system, where 0 indicates seldom or never, 1 sometimes, and 2 often. The results show that households with internet access have a strong tendency to increase their frequency of participation in maintenance, which is consistent with our baseline. Finally, we check the effect of the internet on attendance at village irrigation-related meetings. The estimates in column 4 indicate that internet access is associated with a higher frequency of attending village irrigation-related meetings; again, these results are entirely consistent with our baseline.

7.2 Alternative Measurements of Internet Access

In this part, we employ an alternative measurement of internet access. Some literature uses the frequency of internet use rather than internet access to measure the effect of internet diffusion. In order to reduce the measurement error and be more comparable, we use the frequency of internet use (seldom or often) to measure the effect of the internet. In Table 11, we examine the effect of internet use on the types of irrigation systems. Internet use-seldom is a dummy variable with a value of 1 where use is seldom or never, and 0 otherwise, and Internet use-often is an indicator variable with a value of 1 where use is often, and 0 otherwise. The results in column 4 take into account a full set of control variables and province fixed effects. They show no evidence of a significant correlation between infrequent (seldom) internet use and the choice of a more productive irrigation system. However, households with a high frequency of internet use have a strong preference to select more effective irrigation systems. Therefore, the frequency of internet use is also crucial when considering the effect on the selection of irrigation systems. In other words, only when internet use occurs with high frequency does it impact the production mode.

8 Conclusion

Does the internet affect labor productivity and modes of production? To answer this question, we used confidential household survey data on irrigation and internet access in rural China. The research also exploited a public program to enhance distance education in rural middle schools, which has provided plausibly exogenous variation in internet access. Both our ordered probit estimates and IV estimates show that internet access is associated with a substantial increase in the productivity of irrigation systems.

We presented a conceptual framework that highlights the mechanism whereby internet access may affect the choice of the irrigation system in the agricultural sector. We found a negative direct effect in the agricultural sector and a positive indirect effect in the service sector. Our empirical results suggested that the indirect impact dominates the direct impact, such that the net effect is positive and empirically significant. It is plausible that this is a result of reduced information frictions and searching costs. We explore several possible transmission channels for the productivity improvement via internet access and find suggestive evidence that trust and collective actions among farmers play essential roles.

Taken together, our findings have important implications for the debate about the role of government policies in the expansion of the internet infrastructure in the poor and developing areas. Our estimates suggest that government should allocate more public finance to subsidize the spread of internet access, especially to rural areas. Moreover, our results indicate that infrastructure growth has limited impact unless the local government publishes its information online. That is, local governments should use the internet to disseminate information not only on policy goals, plans, regulations, budgets, and expenditures, but also on irrigation, production, markets, and recruitment.

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Table 1: Variable Definition

Variable	Definition
Dependent Variables (winsorized at the 1% level)	
Household-level	
Irrigation	Irrigation types: 3=open cannel; 2=well; 1=lift; 0=none.
Contribution	Contribution to maintenance:
	4=capital & labor; 3=only capital; 2=only labor; 1=none.
Maintenance	Frequency of maintenance (participated):
	2=often; 1=sometimes; 0=seldom or never.
Meeting	Frequency of irrigation meetings (attended):
	2=often; 1=sometimes; 0=seldom or never.
Justice	Extent of fair and equity in the process of the irrigation system:
	5=very satisfied; 4=satisfied; 3=neutral; 2=dissatisfied; 1=very dissatisfied.
Approve	Construction and maintenance are approved by most of the farmers in the village:
	5=strongly agree; 4=agree; 3=neutral; 2=disagree; 1=strongly disagree.
Monitor	Effectiveness of the supervision by the village coordinating committee:
	5=strongly agree; 4=agree; 3=neutral; 2=disagree; 1=strongly disagree.
Feedback	Organizers of the irrigation system could provide satisfied feedback:
	5=very satisfied; 4=satisfied; 3=neutral; 2=dissatisfied; 1=very dissatisfied; 6=N/A.
Organization	1=having attended any organization, association, or cooperation; 0=otherwise.
Key Explanatory Variables (winsorized at the 1% level)	
Household-level	
Internet access	Access to internet: 1=access; 0=non-access.
Internet usage: seldom	Frequency of the internet usage: 1=seldom or never; 0=otherwise.
Internet usage: often	Frequency of the internet usage: 1=often; 0=otherwise.
Control Variables (winsorized at the 1% level)	
Village-level	
Physical attributes	
Topography	1=plain; 0=hill or mountain.
Location	1=non-suburban village; 0=suburban village.
Moderate water scarcity	1=moderate water scarcity; 0=otherwise.
Severe water scarcity	1=severe water scarcity; 0=otherwise.
Community attributes	
Village size	The number of households
Gini index	Gini index calculated with household income at the village level
Labor migration	Share of households with out-migrants over total households at the village level
Institutional contexts	
Governance failure	1=petitions and conflicts in the last three years; 0=otherwise.
Monitoring & sanctioning rules	1=imposing rules against free riders; 0=otherwise.
Household-level	
Household attributes	
Share of labor	Percentage of labors over the number of family member in a specific household
Moderate distance to irrigation	1=moderate distance to irrigation system; 0=otherwise.
Long distance to irrigation	1=long distance to irrigation system; 0=otherwise.
Past irrigation shortage	5=always; 4=often; 3=sometimes; 2=seldom; 1=never.
Impact of insufficient irrigation	1=bad impact; 0=otherwise.
Age	Age of household head
Education	Household head: 1=education level higher than junior high school; 0=otherwise

Table 2: Summary Statistics

	Mean	Std. Dev.	Min.	Max.
Dependent Variable				
Irrgation	1.402	1.316	0	3
Key Explanatory Variable				
Internet access	0.270	0.444	0	1
Control Variables				
Physical attributes				
Topography	0.299	0.458	0	1
Location	0.821	0.383	0	1
Moderate water scarcity	0.317	0.465	0	1
Severe water scarcity	0.309	0.462	0	1
Community attributes				
Village size	7.482	0.838	5.081	10.37
Gini index	0.412	0.153	0.0965	0.876
Labor migration	0.407	0.205	0	1
Institutional contexts				
Governance failure	0.768	0.422	0	1
Monitoring & sanctioning rules	0.234	0.424	0	1
Household attributes				
Share of labor	0.486	0.189	0	0.857
Moderate distance to irrigation	0.369	0.483	0	1
Long distance to irrigation	0.111	0.314	0	1
Past irrigation shortage	0.421	0.494	0	1
Impact of insufficient irrigation	0.497	0.500	0	1
Age	47.43	14.47	12	93
Education	0.559	0.497	0	1
N	3757			

Table 3: Distribution of Irrigation Types by Different Groups

Variable	None	Lift	Well	Canal
Internet access				
Yes	36.4%	11.6%	16.4%	35.6%
No	43.4%	8.25%	16.5%	31.9%
Topography				
Yes	6.10%	9.61%	41.6%	42.7%
No	56.2%	8.83%	6.26%	28.7%
Location				
Yes	43.3%	8.91%	16.1%	31.7%
No	34.1%	9.76%	18.1%	38.0%
Moderate water scarcity				
Yes	33.8%	9.40%	24.2%	32.7%
No	45.3%	8.90%	13.0%	32.8%
Severe water scarcity				
Yes	54.3%	6.02%	14.2%	25.5%
No	35.6%	10.6%	17.6%	36.3%
Governance failure				
Yes	48.5%	9.18%	13.0%	29.2%
No	20.9%	8.67%	27.0%	43.5%
Monitoring & sanctioning rules				
Yes	26.9%	12.8%	15.8%	44.5%
No	46.5%	7.85%	16.7%	29.0%
Moderate distance to irrigation				
Yes	14.3%	13.3%	24.1%	48.4%
No	60.9%	6.13%	11.2%	21.8%
Long distance to irrigation				
Yes	21.0%	8.75%	16.2%	54.1%
No	44.8%	9.10%	16.5%	29.6%
Past irrigation shortage				
Yes	54.4%	8.47%	9.51%	27.7%
No	33.7%	9.43%	20.9%	36.0%
Impact of insufficient irrigation				
Yes	33.7%	9.76%	19.1%	37.4%
No	52.2%	8.14%	13.0%	26.7%
Education				
Yes	35.9%	11.0%	16.9%	36.2%
No	49.3%	6.56%	15.8%	28.3%

Table 4: Ordered probit estimates of internet access on irrigation: baseline

	(1) Irrigation	(2) Irrigation	(3) Irrigation	(4) Irrigation
Internet access	0.113*	0.145**	0.182***	0.180***
	(0.06)	(0.07)	(0.07)	(0.07)
Topography	0.756***	1.368***	1.311***	1.309***
	(0.06)	(0.08)	(0.08)	(0.08)
Location	-0.0735	-0.168**	-0.101	-0.0637
	(0.07)	(0.08)	(0.08)	(0.08)
Moderate water scarcity	-0.0242	0.185***	0.162**	0.0856
	(0.06)	(0.06)	(0.06)	(0.07)
Village size	0.281***	0.186***	0.140***	0.137***
	(0.03)	(0.04)	(0.04)	(0.04)
Gini index	0.190	-0.429*	-0.252	-0.287
	(0.20)	(0.24)	(0.24)	(0.24)
Labor migration	0.260**	0.0541	0.00382	0.0285
	(0.12)	(0.13)	(0.14)	(0.14)
Governance failure	-0.307***	-0.594***	-0.618***	-0.614***
	(0.06)	(0.07)	(0.07)	(0.07)
Monitoring & sanctioning rules	0.240***	0.125*	0.0628	0.0605
	(0.06)	(0.07)	(0.07)	(0.07)
Share of labor	0.180	0.229	0.175	0.149
	(0.14)	(0.15)	(0.15)	(0.16)
Moderate distance to irrigation	0.801***	0.690***	1.035***	1.038***
	(0.05)	(0.06)	(0.07)	(0.07)
Past irrigation shortage	-0.131**	-0.0885	-0.137**	-0.132**
	(0.06)	(0.06)	(0.06)	(0.06)
Impact of insufficient irrigation	0.190***	0.237***	0.194***	0.192***
	(0.05)	(0.06)	(0.06)	(0.06)
Age	0.0131***	0.00816***	0.00865***	0.00892***
	(0.00)	(0.00)	(0.00)	(0.00)
Education	0.308***	0.174***	0.156**	0.157**
	(0.06)	(0.06)	(0.06)	(0.06)
Long distance to irrigation			1.107***	1.106***
			(0.10)	(0.10)
Severe water scarcity				-0.181**
				(0.08)
Province Fixed Effect		✓	✓	✓
N	2267	2267	2267	2267
R^2	0.150	0.250	0.278	0.279
χ^2	733.6	19370.6	16105.5	16150.0

Notes: Standard errors are heteroskedasticity robust and clustered at the village level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 5: Instrumental variable estimates of internet access on irrigation

	(1) Irrigation	(2) Irrigation	(3) Irrigation	(4) Irrigation
Internet access	2.504***	3.716***	3.284***	3.391***
	(0.79)	(1.44)	(1.27)	(1.30)
Topography	0.676***	1.091***	0.966***	0.960***
	(0.10)	(0.13)	(0.12)	(0.12)
Location	-0.135	-0.0982	0.00392	0.0303
	(0.09)	(0.12)	(0.10)	(0.11)
Moderate water scarcity	-0.123	0.00510	-0.0111	-0.0725
	(0.09)	(0.10)	(0.09)	(0.11)
Village size	0.170***	0.0855	0.0594	0.0567
	(0.04)	(0.07)	(0.06)	(0.06)
Gini index	-0.111	-0.472	-0.324	-0.351
	(0.23)	(0.32)	(0.28)	(0.29)
Labor migration	0.0796	0.159	0.0785	0.101
	(0.16)	(0.20)	(0.18)	(0.18)
Governance failure	-0.302***	-0.474***	-0.444***	-0.438***
	(0.08)	(0.10)	(0.09)	(0.09)
Monitoring & sanctioning rules	0.161**	0.0366	-0.0219	-0.0318
	(0.07)	(0.10)	(0.09)	(0.09)
Share of labor	-0.0375	-0.193	-0.196	-0.223
	(0.18)	(0.26)	(0.24)	(0.24)
Moderate distance to irrigation	0.757***	0.586***	0.927***	0.929***
	(0.07)	(0.08)	(0.09)	(0.09)
Past irrigation shortage	-0.178***	-0.171**	-0.189**	-0.187**
	(0.07)	(0.09)	(0.08)	(0.08)
Impact of insufficient irrigation	0.262***	0.280***	0.208***	0.209***
	(0.07)	(0.09)	(0.08)	(0.08)
Age	0.0241***	0.0286***	0.0259***	0.0266***
	(0.00)	(0.01)	(0.01)	(0.01)
Education	-0.0945	-0.297	-0.274*	-0.289*
	(0.13)	(0.19)	(0.17)	(0.17)
Long distance to irrigation			1.098***	1.100***
			(0.14)	(0.14)
Severe water scarcity				-0.124
				(0.09)
Constant	-1.806***	-0.240	-0.194	-0.192
	(0.40)	(0.62)	(0.56)	(0.57)
first stage				
Distance to school	-0.0518***	-0.0429***	-0.0438***	-0.0444***
	(0.01)	(0.01)	(0.01)	(0.01)
Province Fixed Effect		✓	✓	✓
N	2212	2212	2212	2212
F-statistics	41.62	16.80	21.82	20.36

Notes: Standard errors are heteroskedasticity robust and clustered at the village level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 6: Estimates of internet access on irrigation: full-time farmers

	(1) Irrigation	(2) Irrigation	(3) Irrigation	(4) Irrigation
Internet access	0.120*	0.156**	0.193***	0.191***
	(0.06)	(0.07)	(0.07)	(0.07)
Internet access × full-time farmer	-0.646	-0.883*	-0.958*	-1.025*
	(0.49)	(0.53)	(0.54)	(0.54)
Topography	0.755***	1.369***	1.312***	1.311***
	(0.06)	(0.08)	(0.08)	(0.08)
Location	-0.0721	-0.163**	-0.0957	-0.0569
	(0.07)	(0.08)	(0.08)	(0.08)
Moderate water scarcity	-0.0242	0.186***	0.163**	0.0834
	(0.06)	(0.06)	(0.07)	(0.07)
Village size	0.281***	0.186***	0.139***	0.136***
	(0.03)	(0.04)	(0.04)	(0.04)
Gini index	0.187	-0.431**	-0.254	-0.291
	(0.19)	(0.22)	(0.22)	(0.22)
Labor migration	0.257**	0.0512	0.000684	0.0261
	(0.12)	(0.14)	(0.14)	(0.14)
Governance failure	-0.308***	-0.595***	-0.620***	-0.615***
	(0.06)	(0.07)	(0.07)	(0.07)
Monitoring & sanctioning rules	0.245***	0.132**	0.0698	0.0680
	(0.06)	(0.07)	(0.07)	(0.07)
Share of labor	0.184	0.235	0.182	0.156
	(0.14)	(0.15)	(0.16)	(0.16)
Moderate distance to irrigation	0.803***	0.692***	1.038***	1.042***
	(0.05)	(0.06)	(0.06)	(0.06)
Past irrigation shortage	-0.131**	-0.0892	-0.138**	-0.132**
	(0.05)	(0.06)	(0.06)	(0.06)
Impact of insufficient irrigation	0.191***	0.238***	0.195***	0.192***
	(0.05)	(0.06)	(0.06)	(0.06)
Age	0.0131***	0.00823***	0.00874***	0.00902***
	(0.00)	(0.00)	(0.00)	(0.00)
Education	0.308***	0.175***	0.157**	0.157**
	(0.06)	(0.06)	(0.06)	(0.06)
Long distance to irrigation			1.108***	1.107***
			(0.09)	(0.09)
Severe water scarcity				-0.189**
				(0.07)
Province Fixed Effect		✓	✓	✓
N	2267	2267	2267	2267
R^2	0.150	0.251	0.278	0.279
χ^2	850.9	1421.5	1577.6	1584.1

Notes: Standard errors are heteroskedasticity robust and clustered at the village level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 7: Channels of internet access on irrigation: internet user types

	(1) Irrigation	(2) Irrigation	(3) Irrigation	(4) Irrigation
Irrigation				
Internet access × entertainment	-0.125	0.0708	0.0839	0.0848
	(0.09)	(0.10)	(0.10)	(0.10)
Internet access × shopping	-0.206*	-0.135	-0.0810	-0.0875
	(0.11)	(0.12)	(0.12)	(0.12)
Internet access × social	0.0581	0.0509	0.0884	0.0807
	(0.09)	(0.10)	(0.10)	(0.10)
Internet access × information	0.464***	0.283**	0.231**	0.245**
	(0.11)	(0.11)	(0.11)	(0.11)
Topography	0.803***	1.379***	1.323***	1.321***
	(0.06)	(0.08)	(0.08)	(0.08)
Location	-0.0732	-0.169**	-0.102	-0.0632
	(0.07)	(0.08)	(0.08)	(0.08)
Moderate water scarcity	-0.0163	0.180***	0.159**	0.0789
	(0.06)	(0.06)	(0.06)	(0.07)
Village size	0.295***	0.194***	0.146***	0.143***
	(0.03)	(0.04)	(0.04)	(0.04)
Gini index	0.219	-0.390	-0.212	-0.250
	(0.20)	(0.24)	(0.24)	(0.24)
Labor migration	0.249**	0.0466	-0.00240	0.0232
	(0.12)	(0.13)	(0.14)	(0.14)
Governance failure	-0.321***	-0.598***	-0.622***	-0.618***
	(0.06)	(0.07)	(0.07)	(0.07)
Monitoring & sanctioning rules	0.229***	0.123*	0.0611	0.0589
	(0.06)	(0.07)	(0.07)	(0.07)
Share of labor	0.182	0.232	0.179	0.152
	(0.14)	(0.15)	(0.15)	(0.16)
Moderate distance to irrigation	0.787***	0.682***	1.026***	1.029***
	(0.05)	(0.06)	(0.07)	(0.07)
Past irrigation shortage	-0.134**	-0.0876	-0.134**	-0.129**
	(0.06)	(0.06)	(0.06)	(0.06)
Impact of insufficient irrigation	0.178***	0.229***	0.188***	0.185***
	(0.05)	(0.06)	(0.06)	(0.06)
Age	0.0122***	0.00788***	0.00847***	0.00873***
	(0.00)	(0.00)	(0.00)	(0.00)
Education	0.293***	0.167***	0.152**	0.151**
	(0.06)	(0.06)	(0.06)	(0.06)
Long distance to irrigation			1.098***	1.096***
			(0.10)	(0.10)
Severe water scarcity				-0.189**
				(0.08)
Province Fixed Effect		✓	✓	✓
N	2267	2267	2267	2267
R^2	0.154	0.251	0.278	0.279
χ^2	783.1	19335.4	16222.9	16597.5

Notes: Standard errors are heteroskedasticity robust and clustered at the village level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 8: Channels of internet access on irrigation: online government disclosure

	(1) Irrigation	(2) Irrigation	(3) Irrigation	(4) Irrigation
Internet access	-0.00232	0.0608	0.0895	0.0895
	(0.07)	(0.07)	(0.07)	(0.07)
Internet access × online disclosure	0.378***	0.388***	0.391***	0.384***
	(0.13)	(0.15)	(0.15)	(0.15)
Topography	0.688***	1.265***	1.205***	1.210***
	(0.06)	(0.09)	(0.09)	(0.09)
Location	-0.00586	-0.00545	0.0635	0.0818
	(0.07)	(0.08)	(0.09)	(0.09)
Moderate water scarcity	-0.0995*	0.0684	0.0588	-0.0210
	(0.06)	(0.07)	(0.07)	(0.08)
Village size	0.246***	0.170***	0.118**	0.120**
	(0.03)	(0.05)	(0.05)	(0.05)
Gini index	-0.0496	-0.430*	-0.216	-0.217
	(0.21)	(0.24)	(0.24)	(0.24)
Labor migration	0.368***	0.0820	-0.0216	0.0133
	(0.14)	(0.16)	(0.16)	(0.16)
Governance failure	-0.512***	-0.784***	-0.798***	-0.794***
	(0.07)	(0.07)	(0.07)	(0.07)
Monitoring & sanctioning rules	0.236***	0.131*	0.0580	0.0617
	(0.06)	(0.07)	(0.07)	(0.07)
Share of labor	-0.0310	0.0244	0.00621	-0.00734
	(0.15)	(0.16)	(0.16)	(0.16)
Moderate distance to irrigation	0.823***	0.729***	1.054***	1.059***
	(0.06)	(0.06)	(0.07)	(0.07)
Past irrigation shortage	-0.152***	-0.0736	-0.106*	-0.103
	(0.06)	(0.06)	(0.06)	(0.06)
Impact of insufficient irrigation	0.204***	0.243***	0.215***	0.211***
	(0.06)	(0.06)	(0.06)	(0.06)
Age	0.0116***	0.00733***	0.00791***	0.00818***
	(0.00)	(0.00)	(0.00)	(0.00)
Education	0.297***	0.178***	0.179***	0.183***
	(0.06)	(0.07)	(0.07)	(0.07)
Long distance to irrigation			1.034***	1.032***
			(0.10)	(0.10)
Severe water scarcity				-0.192**
				(0.08)
Province Fixed Effect		✓	✓	✓
N	2028	2028	2028	2028
R^2	0.156	0.254	0.276	0.278
χ^2	798.5	1301.2	1417.6	1423.4

Notes: Standard errors are heteroskedasticity robust and clustered at the village level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 9: Channels of internet access on irrigation: ability and willingness to participate in collective actions

	(1) justice	(2) approve	(3) monitor	(4) feedback	(5) organization
Internet access	0.176***	0.183***	0.153***	0.116**	0.214***
	(0.05)	(0.05)	(0.05)	(0.06)	(0.07)
Village size	-0.210***	-0.160***	-0.191***	-0.107***	-0.0963**
	(0.03)	(0.03)	(0.04)	(0.04)	(0.05)
Gini index	0.0475	-0.204	-0.520***	-0.0297	-0.00765
	(0.14)	(0.15)	(0.16)	(0.16)	(0.20)
Labor migration	-0.260**	-0.466***	-0.190*	-0.196	-0.444***
	(0.11)	(0.11)	(0.11)	(0.12)	(0.15)
Household size	-0.0349***	-0.0251*	-0.00171	-0.0299**	0.00371
	(0.01)	(0.01)	(0.01)	(0.01)	(0.02)
Share of labor	0.350***	0.218*	0.461***	0.298**	0.100
	(0.11)	(0.11)	(0.12)	(0.12)	(0.15)
Household health	0.0357	0.0818*	-0.00270	0.0670	-0.0469
	(0.04)	(0.04)	(0.05)	(0.05)	(0.06)
Age	0.00637***	0.00366**	0.000973	0.000948	0.00125
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Education	0.112**	0.0219	0.193***	0.188***	0.107*
	(0.05)	(0.05)	(0.05)	(0.05)	(0.06)
Constant					-0.461
					(0.42)
Province Fixed Effect	✓	✓	✓	✓	✓
N	2813	2711	2671	2255	2833
R^2	0.0438	0.0376	0.0541	0.0526	0.0828
χ^2	329.3	293.0	1457.4	371.2	223.2

Notes: Standard errors are heteroskedasticity robust and clustered at the village level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 10: Robustness: alternative irrigation levels

	(1) Irr. level	(2) Irr. contribution	(3) Irr. maintenance	(4) Irr. meeting
Internet access	0.180***	0.153***	0.133**	0.139**
	(0.07)	(0.05)	(0.06)	(0.06)
Topography	1.309***	0.330***	0.228***	0.302***
	(0.08)	(0.07)	(0.07)	(0.07)
Location	-0.0637	0.215***	0.141*	-0.142**
	(0.08)	(0.06)	(0.08)	(0.07)
Moderate water scarcity	0.0856	0.0693	-0.0492	-0.0763
	(0.07)	(0.06)	(0.07)	(0.06)
Severe water scarcity	-0.181**	-0.241***	-0.227***	-0.203***
	(0.08)	(0.06)	(0.07)	(0.07)
Village size	0.137***	-0.119***	-0.0537	-0.0434
	(0.04)	(0.04)	(0.04)	(0.04)
Gini index	-0.287	-0.633***	-0.0853	-0.202
	(0.24)	(0.16)	(0.18)	(0.18)
Labor migration	0.0285	0.105	-0.206	0.0216
	(0.14)	(0.12)	(0.14)	(0.13)
Governance failure	-0.614***	0.268***	-0.151**	0.168***
	(0.07)	(0.06)	(0.06)	(0.06)
Monitoring & sanctioning rules	0.0605	-0.0161	-0.155**	-0.00561
	(0.07)	(0.05)	(0.06)	(0.06)
Share of labor	0.149	-0.0167	0.109	0.160
	(0.16)	(0.12)	(0.14)	(0.13)
Moderate distance to irrigation	1.038***	0.194***	0.313***	0.195***
	(0.07)	(0.05)	(0.06)	(0.06)
Long distance to irrigation	1.106***	0.131*	0.299***	0.0744
	(0.10)	(0.07)	(0.09)	(0.08)
Past irrigation shortage	-0.132**	0.354***	0.0750	0.159***
	(0.06)	(0.05)	(0.05)	(0.05)
Impact of insufficient irrigation	0.192***	-0.0587	-0.0950*	-0.149***
	(0.06)	(0.05)	(0.05)	(0.05)
Age	0.00892***	0.00142	-0.00195	-0.000313
	(0.00)	(0.00)	(0.00)	(0.00)
Education	0.157**	0.161***	0.0650	0.0504
	(0.06)	(0.05)	(0.06)	(0.06)
Province Fixed Effect		✓	✓	✓
N	2267	2886	2445	2448
R^2	0.279	0.0559	0.0492	0.0462
χ^2	16150.0	1749.2	2530.2	1895.3

Notes: Standard errors are heteroskedasticity robust and clustered at the village level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Table 11: Robustness: alternative internet access

	(1) Irrigation	(2) Irrigation	(3) Irrigation	(4) Irrigation
Internet access: seldom	-0.0102	0.0157	0.0117	0.00979
	(0.06)	(0.07)	(0.07)	(0.07)
Internet access: often	0.109	0.152**	0.187**	0.184**
	(0.07)	(0.07)	(0.07)	(0.07)
Topography	0.757***	1.367***	1.311***	1.309***
	(0.06)	(0.08)	(0.08)	(0.08)
Location	-0.0747	-0.165**	-0.0986	-0.0621
	(0.07)	(0.08)	(0.08)	(0.08)
Moderate water scarcity	-0.0241	0.185***	0.162**	0.0860
	(0.06)	(0.06)	(0.06)	(0.07)
Village size	0.281***	0.185***	0.139***	0.137***
	(0.03)	(0.04)	(0.04)	(0.04)
Gini index	0.188	-0.427*	-0.250	-0.287
	(0.20)	(0.24)	(0.24)	(0.24)
Labor migration	0.258**	0.0572	0.00606	0.0304
	(0.12)	(0.13)	(0.14)	(0.14)
Governance failure	-0.307***	-0.594***	-0.618***	-0.614***
	(0.06)	(0.07)	(0.07)	(0.07)
Monitoring & sanctioning rules	0.240***	0.125*	0.0625	0.0603
	(0.06)	(0.07)	(0.07)	(0.07)
Share of labor	0.181	0.228	0.174	0.149
	(0.14)	(0.15)	(0.15)	(0.16)
Moderate distance to irrigation	0.802***	0.689***	1.034***	1.038***
	(0.05)	(0.06)	(0.07)	(0.07)
Past irrigation shortage	-0.131**	-0.0882	-0.137**	-0.132**
	(0.06)	(0.06)	(0.06)	(0.06)
Impact of insufficient irrigation	0.190***	0.237***	0.195***	0.192***
	(0.05)	(0.06)	(0.06)	(0.06)
Age	0.0130***	0.00821***	0.00870***	0.00895***
	(0.00)	(0.00)	(0.00)	(0.00)
Education	0.309***	0.173***	0.155**	0.156**
	(0.06)	(0.06)	(0.06)	(0.06)
Long distance to irrigation			1.107***	1.106***
			(0.10)	(0.10)
Severe water scarcity				-0.181**
				(0.08)
Province Fixed Effect		✓	✓	✓
N	2267	2267	2267	2267
R^2	0.150	0.250	0.278	0.279
χ^2	733.6	19304.1	16082.3	16137.0

Notes: Standard errors are heteroskedasticity robust and clustered at the village level. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.