How Does Information and Communication Technology Influence Agricultural Development: Evidence from China

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Abstract

Information and Communication Technology (ICT) such as the world-wide application of mobile phones and internet have contributed substantially to the fast-growing world economy in unprecedented ways. Our research focuses on the influence of those two technologies and tries to answer the question, “how does ICT influence agricultural output in China?” Through an empirical analysis utilizing panel data from 27 provinces of China across a period of 10 years, our results indicate that in spite of our previous prediction that those two technologies contribute positively to the development of Chinese agriculture, we see negative influence of mobile phones and positive influence of internet. Possible explanations and further discussions are provided.

Introduction

Agriculture, known as the primary industry of the modern world, has been experiencing constant development throughout human history and especially rapid changes over the last few decades. For the purpose of this paper, we define “agriculture” as the combination of farming, forestry, animal husbandry and fishery activities according to the definition by the National Bureau of Statistics of China (NBSC) (2013-2012). It is commonly accepted that technology advancements are the keys to a more developed economy. We hence deduce using the same rationale that agriculture development is affected by technological changes as well. A few honorable mentions of such technological changes may be the mechanization of farming equipment, development of multiple-field crop rotation as well as the development of fertilizers in the Green Revolution (Sunding and Zilberman, 2001). While these technological changes were mainly focused on the physical production of crops, livestock or fishery, more recent technological advancements like the introduction of Information and Communication Technology (ICT) emphasize on a broader aspect, including production, transportation, communication, marketing, reproduction and even education. The effects of these ICTs on the world economy have been studied systematically by many scholars but we intend to focus on the effects on the agricultural sector of China which, considering the rising status of China as a world-class economy, received little attention. That might be due to the fact that China has only been experiencing rapid growth for the last few decades and the agricultural sector even more recently. Complete and systematic data are difficult to obtain as a result of the less-developed statistics department of the Chinese government, local and central. For the purpose of this research, we selected two of the most prominent information technology realizations as our observation: internet and mobile phone. A survey conducted in 2014 showed that out of 1.26 billion people in China, 886 million mobile connections have been established which attributes to 405 million mobile subscribers, surpassing the total population of the United States. While the Chinese rural area has been experiencing relatively slow development compared to urban counterparts, on average the rural population actually possess 1.18 SIM cards per person which means everyone is accessible to mobile phone coverage (Gillet, 2014). On the other hand, the internet penetration rate reached 62.8 percent for the urban population in 2014. The rural area however enjoys a much lower penetration rate at 28.8 percent which accounts for 178 million users as for 2014. What's more interesting is the interaction of mobile phone and internet since 71.3 percent of rural netizens actually access the internet through mobile phone networks (China Internet Network Information Center (CNNIC), 2014). As we can see from Graphs 1.1, 1.2, 1.3, gross output of agriculture, mobile phone ownership and computer ownership all show a similar increasing trend over the decade. Mobile phone and Internet are inevitably two of the most influential and representative ICTs in the early 21st century not only because of their rapid penetration of everyday life, but also the influence on almost every industry. According to Chu (2013), Internet positively impacts the economy since "it spreads information, stimulates innovation, builds up network, fosters business, deepens capital, improves labor market, strengthens market competition, and helps firms to profit from emerging markets." As the Era of Information dawned on us in the late 20th century, we are curious to find out how much benefit, if any, the information and communications technology would bring to agriculture, the oldest industry in the world and that was our motivation to carry out this research.

The following essay will be arranged as follows: Section 1 gives an overview and discussion of the literature we found pertaining to the effects of ICT on agriculture as well the national economy. Section 2 introduces our empirical model and the methodology we will use to analyze the data we found. Section 3 shows the results on which accordingly we will have our discussion and what could be improved. Section 4 concludes.

1. Literature Review

ICT Influence on National Economy

The positive influence of information and communication technology on a country's economy has been studied thoroughly by many scholars. Early research conducted by Hardy (1980) collected data from 60 nations over a period of 13 years, stating that telecommunication does contribute to economic development and furthermore the contribution comes from the support of telecommunication on the organization of economic activities. He continues to conclude that telecommunication investment showed the largest effect in the least developed countries while the most developed countries received the smallest benefits, which indicates that telecommunication development in countries with less developed infrastructure actually brings more benefits than in developed countries. Fuss et al. (2005) specify by suggesting that mobile phones instead of personal computers are actually the driving force of closing the digital divide between the developed and developing countries (Fuss et al., 2005). Yi and Choi (2009) stated that through their research they found a positive and significant role of internet in the development of a country's economic growth. Using their empirical model (model 1.1), they utilized a macroeconomic approach with cross-country data controlling variables of investment ratio, government consumption ratio and inflation rate to estimate the effect of the internet on the national economy. Their results show that every 1 percent increase in internet user ratio could lead to a 0.057 percent increase in GDP growth rate.

More studies were conducted to determine the influence of ICTs on economic factors. According to Norton (1992), ICT infrastructure significantly lowers the cost of acquiring information and various costs of participating in markets. He further states that it is also plausible to argue that a low telecommunication infrastructure is one reason why some parts of the world have not developed. Röller and Waverman (2001) argue that as ICT infrastructure improves, transaction costs reduce, and output increases for firms in various sectors of the economy. Yet different from the view of Hardy (1980), the authors conclude through their empirical analysis that an increase in telecommunication infrastructure could create higher growth effects in OECD (Economic Co-operation and Development) countries than in the less-developed non-OECD countries.

ICT Influence on Agriculture

Thysen (2000) noticed a rather modest use of ICT among farmers and explained by saying that farmers could obtain higher agricultural output by simplification of farming methods and application of cheap externally produced inputs such as fertilizers and pesticide. Nonetheless, the development of ICT and more restriction on use of chemical in agriculture would result in an inevitable decrease in cheap agricultural methods and increase in the application of ICT, which is deemed as sustainable and variable. Some potential ways of an ICT application may be: high precision application of chemicals, caring livestock, food documentation and agricultural extension (which will be discussed later in detail). Some scholars have explored the real-life application of the functions above. McKinion et al. (2004) introduced the wireless local area networking (WLAN) system in the Paul Good Farm in Noxubee County, MS, USA, which wirelessly connected cotton pickers, spray equipment, variable rate fertilized application equipment, and hand-held personal digital assistant computers in the field, allowing for rapid bi-directional movement of data and information. Another survey conducted by Burke and Sewake (2008) focused on the influence of internet on small flower farms in Hawaii, USA. Their results suggested that the internet could potentially boost agricultural sales by presenting the case in which 18 percent of the survey participants saw more than a 75 percent increase of flower sales after their adoption of a computer and an internet network.

Mobile phone technology enjoyed even more attention from researchers because of their widespread application in the world economy, especially the less-developed economies. Many surveys and cross-country analyses have been conducted to determine the effect of mobile phone adoption and application. Sridhar et al. (2007) argues that the average prices of agricultural commodities are higher in villages with access to mobile phones than the ones without. Parker (2005) found that in 2004 there were more new mobile phone subscribers in Sub-Saharan Africa than the whole of North America. Muto and Yamano (2009) found out through their survey in Uganda that mobile phone coverage in the urban and rural areas has a positive and significant influence on prices of agricultural commodities. They also suggested that it was not necessarily the personal possession of mobile phones but the simple expansion of mobile phone coverage in remote areas that increased the prices because the application of mobile phones eliminated the information asymmetry in remote rural areas by giving the farmers the opportunity to find the highest bidders for their commodities. Other research carried out by Mittal et al. (2010) points out that "the introduction of mobile phones decreased price dispersion and wastage by facilitating the spread of information", which leads to more efficient markets and increased social welfare. They categorize the benefits of mobile phones into: "easy access to customized content, mobility and timesaving or convenience". They also suggest that despite the acclaimed usefulness of mobile phone application, these benefits would be unevenly distributed between rural population with lacking policy guidance from the government and underdeveloped infrastructure.

ICT for Agricultural Extension

Besides the influence of mobile phones and internet on the production and marketing aspect of agricultural output, these ICTs are also implemented to improve the education level of agricultural participants. According to Birhaeuser et al. (1991), agricultural extension services are one of the most common public sector supports of knowledge diffusion, which bridges the gap between discoveries in laboratories and changes in individuals' farms. Aker (2011) also states that through the so-called "agricultural extension" programs the rural population could gain access to information and knowledge they need in agricultural production by receiving technological advice from experts via newly introduced ICTs. An example would be that they could receive SMS from mobile phones, which are less expensive than landline phones and more ample in content than radio. Some mobile phone applications also address difficult problems by providing complimentary services via the internet network, such as access to credit or savings, or agriculture and health insurance. Besides the knowledge diffusion function, agricultural extension programs also serve as the feedback units for the individuals' farms, which express their concerns and questions to the public agencies (Birhaeuser et al., 1991).

Empirical Models in the Literature

We found several articles containing empirical models about the relationship between national GDP or agricultural output (level or growth) and ICTs. One is by Shenggen and Zhang (2004) (model 1.2).

They constructed this model to estimate the influence of infrastructure like road (ROADS), percentage of irrigated area in total cropped area (IR), research and development staff (RD), education level (SCHY) and number of rural telephone sets per thousand rural residents (RTR) on both agricultural and non-agricultural outputs. The simultaneous equation system eliminates the potential endogenous problems present in the agricultural production function, in which the first equation represents the influence of variables like land (LAND), agricultural labor force (AGLABOR), fertilizer (FERT), machinery (MACH) on agricultural output (AY) and the second equation the influence of electricity, road, etc. on non-agricultural output (NAY) represented by the gross value of the township and village enterprises (TVE)[1]. This model inspired us since it utilized a simultaneous equation system where the variables of concern were used to estimate outputs of agricultural and non-agricultural sectors in rural areas, which was designed to eliminate the endogeneity problem. We encountered similar problems in our research.

Another model was presented by Lin (1992) (model 1.3), where in equation (1) the author uses variables land, labor, capital, chemical fertilizer (Fert), the index of market prices relative to manufactured input prices (MP), the index of above-quota prices relative to manufactured input prices (GP), the percentage of total sown area in non-grain crops (NGCA) (we used cultivated land area in our research instead since sown land area potentially overestimates the land cultivated because of multiple cropping), the multiple cropping index (MCI), ratio of households converted to Household Responsibility System (HRS), and a time trend (T) to study the influence of HRS on the rural economy. Similar to the previous model, this model utilized some common factors like land, labor, capital and fertilizer while introducing some more problem-specific variables to estimate the influence of HRS.

2. Methodology

We built our own empirical model on those presented above in the literature review (model 2.1).

The data set used for our study was collected by the National Bureau of Statistics of China (NBSC, 2003-2012) which possesses governmental authority and credibility (table 2.1). The data set includes individual data for 27 selected provinces across China for the time period of 2003-2012, which gave us 270 observations for each variable for the panel data (some missing values are present). Our variables include gross output value of farming, forestry, animal husbandry and fishery (Y), sown land area (Land)[2], number of rural employed persons in farming, forestry, animal husbandry and fishery (Labor), consumption of chemical fertilizer (Fertilizer), major agricultural machineries (Machinery), number of mobile phones owned per 100 rural households (Mobile) and number of computers owned per 100 rural households (Computer). The choice of which variables to include in our study was largely affected by the availability of data. The year 2003 is set as our base year since NBSC only provided data for the number of computer

[1] Township and Village Enterprises (TVE) are market-oriented public enterprises mostly in the secondary sector, under the purview of local governments based in townships and villages in the People's Republic of China.

[2] Cultivated land area would have been a better choice since it eliminates the possibility of multiple cropping in agricultural practices but once again, we were unable to obtain credible data from credible sources for this variable.

ownership in rural areas starting from then. Based on our previous investigation, the number of SIM card subscribers and internet users are preferred in representing the penetration of mobile phones and internet. Nevertheless, through our search for the data, neither provincial level data nor rural area data were reachable for us. We then took an alternative route by using the data of total quantity of mobile phones and that of computers possessed by rural households in our study.

In this analysis, Beijing, Tianjin, Shanghai, Chongqing, Hong Kong and Macau were considered outliers and not included in our data set due to their special status and relative lack in agricultural activity engagement. For the rest 27 provinces, we obtained their gross output values of farming, forestry, animal husbandry and fishery of each year, and calculated the real gross output values by deflating the nominal values by agricultural product price indices (Base year=2003). The number of employees in the corresponding sectors in rural areas was available and directly used in our study. Machinery here is represented by the total power (in 10000 kW) consumed at the end of each year. Volume of the effective component of chemical fertilizer is measured in 10000 tons and is the sum of Nitrogenous fertilizer, Phosphate fertilizer, Potash fertilizer and Compound fertilizer. Land area is the total sown areas of farm crops in 1000 hectares. The levels of mobile phone and computer ownership were obtained by multiplying the number of mobile phones or computers owned per 100 rural households by the number of rural households and divided by 100.

To eliminate the potential time-invariant errors and obtain robust estimates for data that is collected in the same way and from the same sample group, fixed effect estimation is preferred to random effect estimation (Borenstein et al., 2010). Also, from the results we could see that random effect estimation gave exactly the same numbers as the standard OLS regression.

As we learned from the literature survey, there exist potential endogeneity problems between the mobile phone penetration rate and the error term. Also, feedback could be present in our model since we cannot determine the causality between agricultural output (in terms of real income) and mobile phone ownership (Graph 2.1, 2.2). We opt for a two-stage least square model in hope of eliminating this feedback effect as well as the potential endogeneity problems between variables *Mobile* and the gross output values of the agriculture sector. The choice of instrument variable was a challenge for us because of the insufficient data problem mentioned above. We tried to use variables like the research and development (R&D) expenditure, prices of mobile phones, gross output of TVEs, etc. None of them showed the capability as a potent IV. Based on our research, we then picked the total enrollment in tertiary education (regardless of age, expressed as a percentage of the total population of the five-year age group following on from secondary school) as the instrument variable. The data we obtained on *Tertiary* was collected by the World Bank (2003-2012). Despite the missing data in 2003 and 2004, the school enrolment rate of tertiary education works well as an instrument variable since it shows high correlation with *Mobile* and low correlation with *Y*. The coefficient of *log(Mobile)* (-1.10), however, is unreasonably large and negative, which lacks economic significance. Furthermore, although the variable *tertiary* showed promising candidacy as an IV, the data were collected from the national level instead of the provincial, rural level which does not fit into our research framework perfectly. After consideration, the second instrumental variable we used was the mobile phone penetration rate of urban areas for the corresponding provinces we studied in the same time period. This instrumental variable gave us better results and is included in our final model.

3. Results and Discussion

Results are shown in table 3.1.

We first ran OLS regression with the total number of mobile phones and computers owned by the rural households and found the estimate for mobile phones was not significant (indicated by OLS*). The output we obtained by running OLS regression to our structural equation with the penetration rates of mobile phones and computers, however, indicated that both of these two variables have significant influences on our dependent variable. The explanation for the differences in these two results could be that it is the penetration rate instead of the level of mobile phones and computers that determines the change in agricultural output values, which aligns with the conclusion of a previous study by Muto and Yamano (2009).

The fixed effect estimation shows very similar results to the OLS, which suggests that there did not exist significant time-invariant errors and the OLS results are already quite robust.

The first stage of our two-stage least squares estimation showed a significant influence of the mobile phone penetration rate in urban areas on the growth rate of mobile phone penetration rate in rural areas and the R-square of the first stage regression was 0.8310, both indicating that *Urban* is a good instrument variable here. The second stage output did give us a significant estimate of -0.066 on *log(Mobile)*, that is, with a 1 percent increase in the number of mobile phones, the gross output values of agriculture sector decrease by 0.066 percent. This result, however, does not match our assumption that the increasing penetration of mobile phones will boost gross agricultural output.

The unexpected negative estimate of *log(Mobile)* could be explained in a few ways. Based on the literature we reviewed, though Chinese rural population have good access to mobile phones and related infrastructure, they mainly use mobile phones for entertainment or daily communication, which does not have much involvement with agricultural activities. Also, according to a previous study by Abraham (2006), instant information has greater influence on perishable goods than non-perishable goods in terms of market prices. In China, rice, wheat and corn are the major planted crops and the market prices of these products might not be significantly affected by faster access to market information, thus no positive impact on the gross output values. Another reason for increasing mobile phone penetration hampering agricultural output could be that with access to more opportunities, people in rural areas might leave farmlands and turn to other businesses, especially TVEs that have been rapidly established across Chinese rural areas. Taking into account the cultural background of China that rural households are eager to leave the countryside and get their *"Hukou*[1]*"* transferred to urban cities, there is a greater chance of participants in the agriculture sector leaving farmland and seek more profitable jobs with more information provided (Chan and Zhang, 1999). In order to corroborate this hypothesis, we tried to use the variables like migration population to estimate the agricultural output but the data for migration population only started being recorded from 2012, in quarters and at the national level, which is incompatible with the other variables we have.

Another challenge we encountered in the analysis was to determine the usefulness of the variable *Land*, which is controversial to be included in the model. We took the data on sown areas of farm crops, which is only related to the farming sector. No data equivalent to land areas could be obtained to explain variation in the change of gross output values due to other sectors of agriculture, namely animal husbandry, forestry and fishery. Although data for the areas of orchard or aquaculture area are available, there are too many missing values in the data set and considered to hamper the significance of the variables. Empirically, the OLS results showed that the variable *Land* does not have statistical significance in our model. Since we tried to limit our area of study to the agriculture sector only, we have been encountering similar problems when carrying out the study due to the insufficient data we could obtain from credible sources, especially the NBSC.

4. Conclusion

Information and communications technology has induced great changes to the modern world. China, as one of the most rapidly developing countries, undoubtedly has also benefited from the introduction of ICT in many different ways. We are curious whether or not these changes also apply to the agriculture sector which is known to be labor-intensive and suffers low total factor productivity. We used two variables of concern, mobile phone and computer, to estimate the influence of mobile phone and Internet penetration rates on the agricultural output of rural China. By running an IV regression, we found that there are significant relationships between mobile phone and agricultural output as well as computer and agricultural output. While the latter one exhibits a positive relationship, as we predicted, the former one contradicts our hypothesis by showing a negative relationship. Although this result took us by surprise, we did find strong evidence supporting it from our extended literature review. One survey from CNNIC suggests that mobile phones in rural China are generally used for entertainment instead of an agricultural purpose. Studies by Chan and Zhang (1999) also suggest that with the introduction of ICT in rural China, agricultural participants would choose to leave the farmlands and look for more lucrative jobs in cities, which actually drags down the agricultural production. We intended to corroborate these statements by running our own regressions but due to the lack of data from the NBSC and other credible sources, we were unable to obtain a robust conclusion. Nonetheless, our result

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[1] A **hukou** is a record in the system of household registration required by law which officially identifies a person as a resident of an area and includes identifying information such as name, parents, spouse, and date of birth. This system is criticized for its entrenchment of social strata, especially as between rural and urban residency status.

and other literature all lead to the same point: while ICT is known to bring positive changes across the world, some part of it does not empirically benefit the agricultural sector as we expected. This conclusion is as interesting as it is troubling since we are now faced with more questions that need solving in the future. How can we exploit ICT to reap the most benefits for the agricultural sector? Or is it beneficial to keep developing ICT in rural areas when there are more cost-effective methods available? With more focus on high-quality agricultural development in the recent years and hopefully more established statistical departments within the Chinese government, we might be able to solve these questions for China, and even the world economy.

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Appendices

Model 1.1:

$$Growth_{it} = \beta_0 + \beta_1 Internet_{it} + \beta_2 Investment_{it} + \beta_3 Government_{it} + \beta_4 Inflation_{it} + u_{it}$$

Model 1.2:

AY = *f*(LAND, AGLABOR, FERT, MACH, IR, RD, SCHY, ROADS, RTR),

NAY = *f*(RILABOR, ELEC, SCHY, ROADS, RTR).

Model 1.3:

$$(1)\ ln(Y_{it}) = a_1 + a_2 (Land_{it}) + a_3 ln(Labor_{it}) + a_4 ln(Capital_{it}) + a_5 ln(Fert_{it}) + a_6 HRS_{it} + a_7 MP_{t-1} + a_8 GP_t + a_9 NGCA_{it} + a_{10} MCI_{it} + a_{11} T_t + \sum_{j=12}^{39} a_j D_j + e_{it}$$

$$(2)\ ln(Y_{it}) = \beta_1 + \beta_2 HRS_{it} + b_3 MP_{t-1} + b_4 GP_t + \beta_5 T_t + \Sigma_{(i=6)}^{33} \beta i Di + \mu_{it}$$

Model 2.1

$$logMobile_{it} = b_0 + b_1 log(Labor_{it}) + b_2 log(Machinery_{it}) + b_3 log(Fertilizer_{it}) + b_4 log(Land_{it}) + b_5 log(Urban_{it}) + \beta_6 lo$$

$$logY_{it} = \beta_0 + \beta_1 log(Labor_{it}) + \beta_2 log(Machinery_{it}) + \beta_3 log(Fertilizer_{it}) + \beta_4 log(Land_{it}) + \beta_5 log(Mobile_{it}) + \beta_6 log(Computer_{it}) + \varepsilon_{it}$$

Table 2.1 Data Summary

Variable	N	Mean	St. Dev	Min	Max
Y (in 100 million yuan)	261	1339.5	837.0	58.6	3870.9
Mobile (number of mobile phones per 100 households)	270	102.0	64.6	2.3	244.5
Computer (number of computers per 100 households)	264	6.5	8.9	0.1	47.9
Labor (in 10000 persons)	270	1035.4	704.9	84.4	3321.2
Machinery (in 10000 kw)	270	2909.5	2645.9	181.2	12419.9
Fertilizer (in 10000 ton)	270	186.0	135.1	3.19	684.4
Land (in 1000 hectare)	270	5641.9	3435.7	231.2	14262.2

Source: CNNIC

Table 3.1 Regression Results

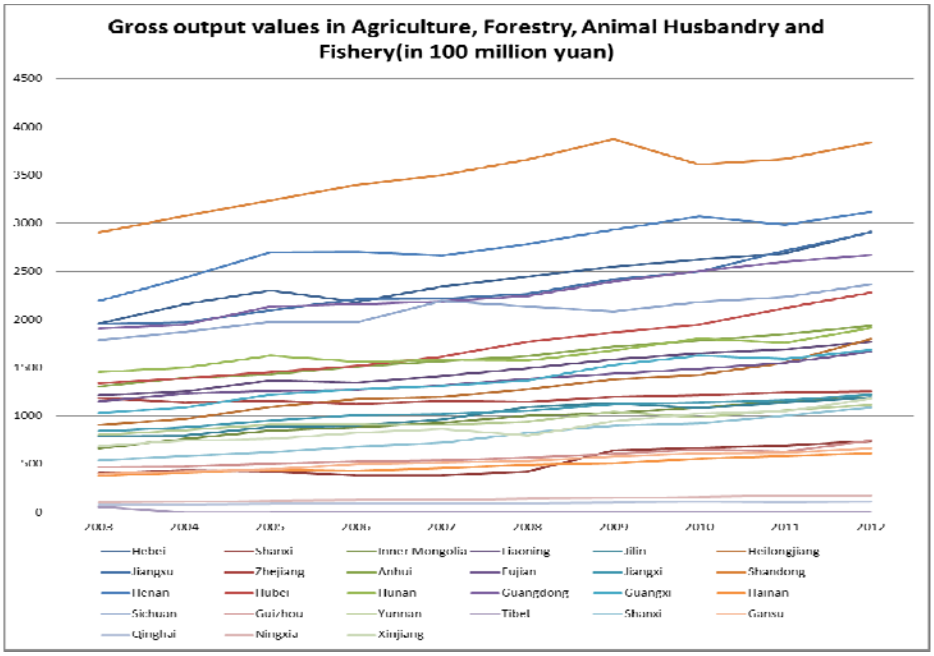
Variable	OLS	OLS*	FE	2SLS
log(Machinery)	-0.105** (0.048)	-0.084** (0.048)	-0.110** (0.051)	-0.103** (0.048)
log(Land)	-0.105 (0.069)	-0.093 (0.069)	-0.080 (0.073)	-0.106 (0.069)
log(Fertilizer)	0.782*** (0.782)	0.787*** (0.556)	0.766*** (0.058)	0.784*** (11.06)
log(Labor)	0.150*** (0.039)	0.170*** (0.042)	0.135*** (0.048)	0.151*** (0.039)
log(Mobile)	-0.078*** (0.021)	-0.047 (0.039)	-0.070** (0.034)	-0.066*** (0.024)
log(Computer)	0.131*** (0.014)	0.127*** (0.024)	0.141*** (0.017)	0.127*** (0.015)
Constant	3.687*** (0.275)	3.251*** (0.260)	3.630*** (0.318)	3.612*** (0.285)
R-square	0.9109	0.9034	0.9104	0.9108

*10% significance level, **5% significance level, ***1% significance level

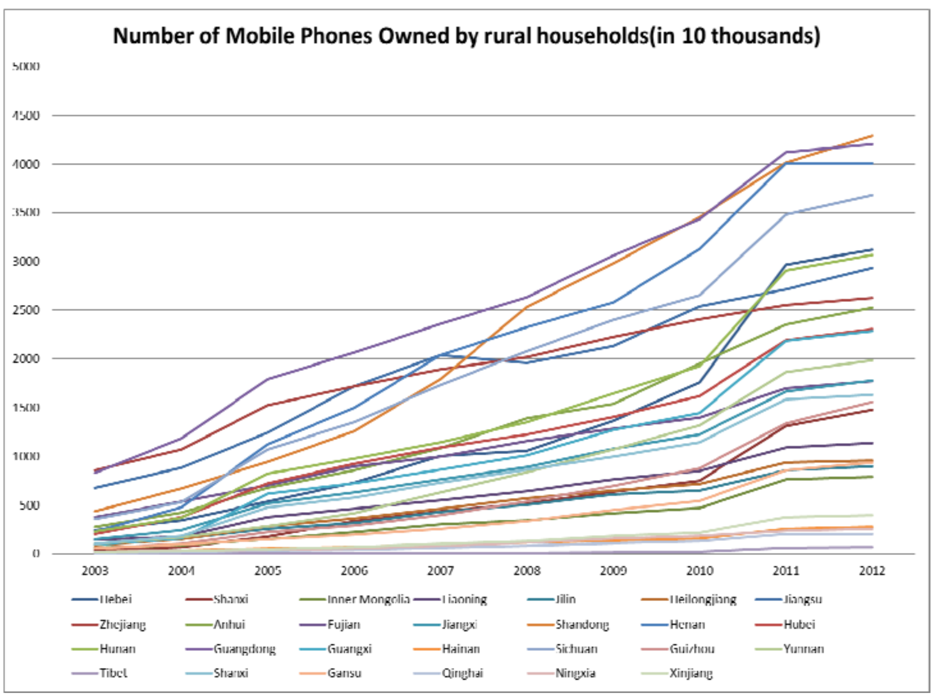
(Standard Error)

Source: results of regression

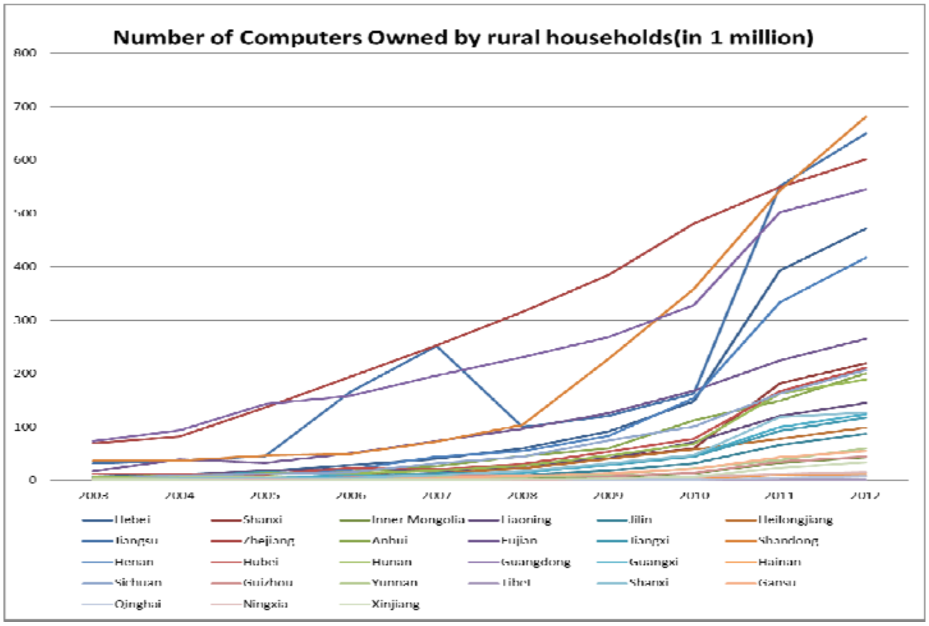
Graph 1.1



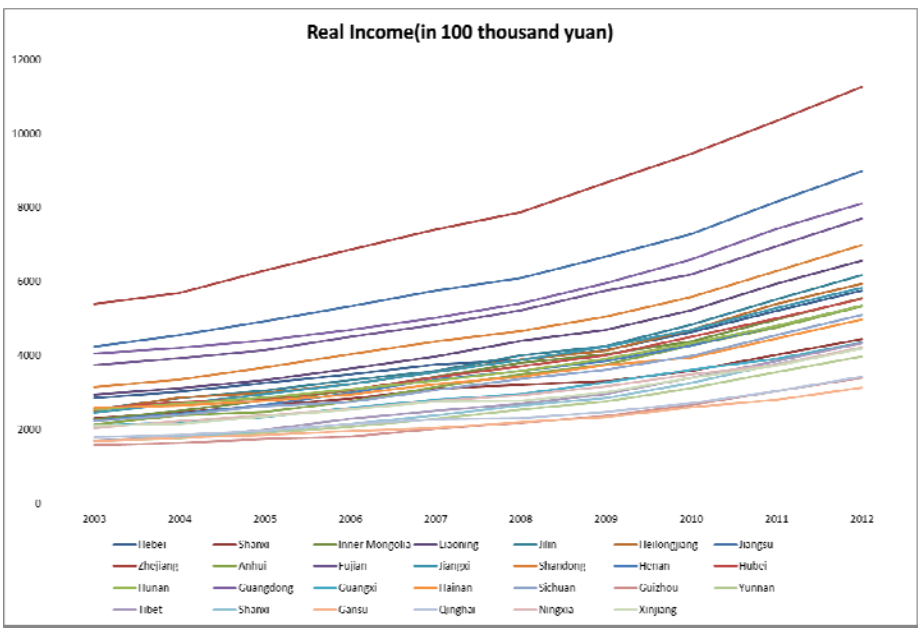
Graph 1.2



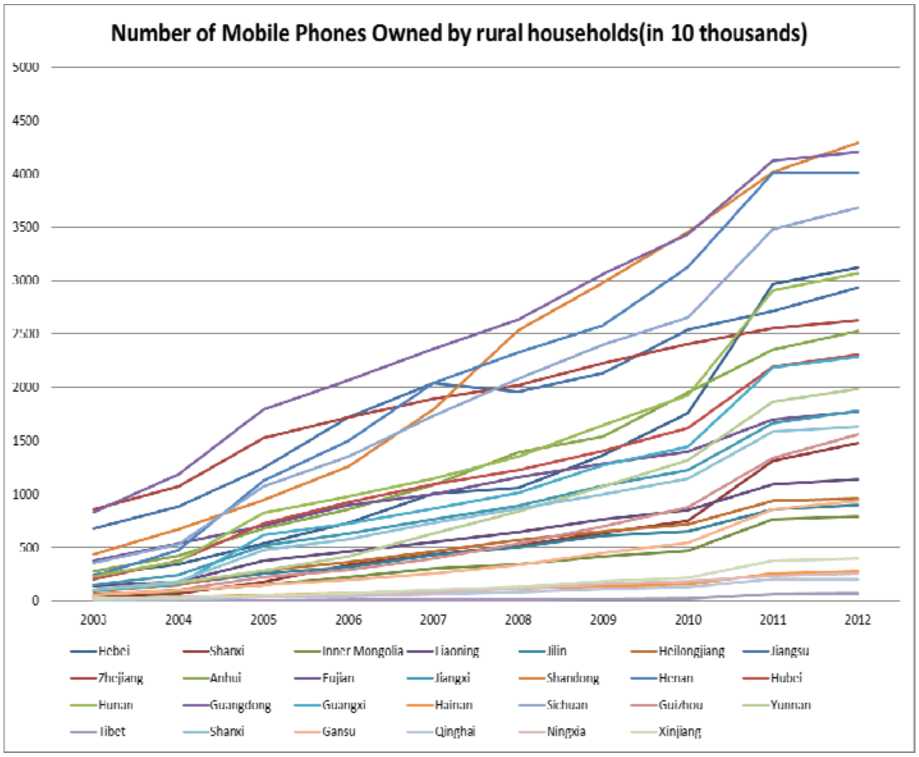
Graph 1.3



Graph 2.1



Graph 2.2


Number of Mobile Phones Owned by rural households(in 10 thousands)
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
Hebei
Shanxi
Inner Mongolia
Liaoning
Jilin
Heilongjiang
Jiangsu
Zhejiang
Anhui
Fujian
Jiangxi
Shandong
Henan
Hubei
Hunan
Guangdong
Guangxi
Hainan
Sichuan
Guizhou
Yunnan
Tibet
Shanxi
Gansu
Qinghai
Ningxia
Xinjiang