STUDY ON THE DEVELOPMENTAL EFFICIENCY EVALUATION OF RURAL INFORMATIZATION IN CHINA AND ITS INFLUENCE FACTOR ANALYSIS
/
中国农村信息化发展效率测度及影响因素分析

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Abstract: *Rural informatization is an inevitable requirement of agricultural development. In the paper a two-phase model with DEA-Tobit was adopted to analyze the developmental efficiency and the influencing factors of rural informatization in China during 2007-2010. The results showed that, on the whole, the overall developmental efficiency of rural informatization in the Middle and Northwest China was lower than that in other regions of China. In addition, the decisive influencing factors on developmental efficiency of rural informatization were resulted from the nation's macro policy and the global construction of rural informatization projects. The level difference in regional economic development was the main reason for the variation in developmental efficiency. Moreover, the structure and level of consumption by rural residents was an important source that had affected the developmental efficiency. Furthermore, the age of rural population and the education level had a significant influence on the developmental efficiency of rural informatization.*

Keywords: *Rural Informatization; Developmental Efficiency; DEA; Tobit Model*

INTRODUCTION

With the development of information technology and the advance of agricultural globalization, governments all over the world have attached great importance to the development of rural informatization. Since the 21st century, rural informatization has been a continual concern by Chinese central government in its No. 1 Document. Rural informatization has been comprehensively organized, promoted and implemented by the central government and institutional sectors at all levels, therefore great progress has been made in rural informatization. However, constrained by various factors such as lack of technical equipment, funding and human resources, the rural informatization in China is still less developed compared with other countries in the world (see Table 1). What is the status quo of rural informatization? What factors influence the development of rural informatization? Study and answer of these two questions will contribute to a reasonable resource allocation, the structural optimization of construction and improvements to management strategy when further studying the development of rural informatization.

摘要：*农村信息化是现代农业发展的必然要求。本文运用DEA-Tobit两阶段法对2007-2010年间中国农村信息化发展效率及影响因素进行了研究分析，研究发现，整体上来看，中部和东北地区的农村信息化整体发展效率低于全国其他区域；农村信息化发展效率的决定性影响因素源于国家全局性农村信息化宏观政策及全局性农村信息化项目的建设；地区经济发展水平差异是造成发展效率差异的原因；农村居民消费结构和消费水平是影响发展效率的重要原因；农村人口年龄和文化程度结构同样显著影响农村信息化发展效率。*

关键词：*农村信息化; 发展效率; DEA; Tobit模型*

引言

随着信息技术的发展和农业全球化浪潮的推进，各国对农村信息化的重视正与日俱增。进入新世纪以来，中国政府一号文件持续关注农村信息化，政府及各机构部门组织、推动、实施的农村信息化建设全面展开，农村信息化取得了巨大的进步。然而由于存在技术设备、资金和人力资源等方面的制约，相对于世界其他国家，中国农村信息化发展仍然滞后（见表 1）。农村信息化目前的发展现状如何？哪些因素影响着农村信息化的发展？研究并回答这两个问题，有助于在农村信息化后续发展中合理配置资源、优化建设结构、完善管理策略，具有积极的现实意义。

Table 1

Characteristic and current status of rural informatization in 5 countries all over the world (2013)

Country	Infrastructure of informatization	Environment of informatization	Stage
United States	Powerful information infrastructure Internet access : 67 percent of the farms Computers per 100 farmers: 68	Adequate funds Perfect legislation Advanced modern information technology	Developed
France	Complete and sound infrastructure Internet access : 50 percent of the farmers	Multi-level pattern of rural information service Diversification of service provider Well-established policy environment	Developed
Japan	Complete rural information infrastructure Computers per 100 farmers: 34 Internet access : 12 percent of the farmers	Government-led investment Focus on the construction of information systems services	Developed

Country	Infrastructure of informatization	Environment of informatization	Stage
India	Imperfect Infrastructure Low popularizing rate of telephone and computer Telephones per 100 farmers:39.29 Wireless users: 345.85 million farmers	Developing the application of agricultural information service Public-private partnerships Priority to the development strategy of Rural informatization Extra subsidy	Developing
China	Inadequate infrastructure Rapidly increasing Fixed telephones per 100 farmers:42.2 Computers per 100 farmers: 21.4	Government-led investment Mobilizing all positive senses of farmers Focus on the development of network system and database construction Extra subsidy	Developing

Sources: U.S. Department of Agriculture [11]; European Commission[1]; Ministry of Agriculture, Forestry and Fisheries of Japan [7]; Ministry of Agriculture of India[8]; National Bureau of Statistics of China[10].
Note: According to present research achievements [4-5], the indexes system for the measurement of rural informatization level consists of six categories of the resources, infrastructure, technology application, industry, human resource and external environment of rural informatization. In Table 1, this paper chooses three indicators of infrastructure, technology application and external environment to analyze and compare characteristic and current status of rural informatization in 5 countries all over the world.

To date, studies on rural informatization of China can be grouped into the following aspects: 1) theoretical studies of strategies and suggestions for rural informatization development, which includes the improvement of the policy system for rural informatization development (Yang Cheng, 2009)[13] and the market development strategies for rural informatization products (Ma Mingyuan et al., 2009)[9]; 2) comparative studies of rural informatization in China and abroad about domestic and overseas experiences and lessons in rural informatization development, and the advantages in Chinese rural informatization process (He Hongming et al., 2011)[2]; 3) detailed technical frameworks and schemes, in which the platform construction of rural informatization is discussed (Zhou Wei, 2011)[14]. This part emphasizes on technology although literature for reference is lacking; and 4) evaluative studies on rural informatization construction. As rural informatization construction has further deepened, literature in this area has also increased; however, most studies are restricted to the evaluation index system of rural informatization and comparison among different levels of informatization in different regions on the basis of the evaluation index system(Zhou yuefeng, et al., 2011)[15]. It is noteworthy that only a small number of studies analyzed influencing factors in rural informatization. The specific methods employed in these studies include regression analysis (Liu Chunnian et al., 2006)[6], grey relational analysis (Wang Shuangying, 2008)[12], and factor analysis (Zhao Hui et al., 2010)[16]. Other studies in this area have characterized rural informatization as a social economic phenomenon and discussed the relationship between rural informatization and other social phenomena, e.g., the relationship between rural informatization and rural income (Zeng Shuoxun et al., 2010)[17], the relationship between rural informatization and economic development (Huang Zhiwen)[3], and the effects of rural informatization on improving farmers livelihoods (Zhang Li et al., 2011) [18] etc.

The paper belongs to the fourth aspect above. Through analysis of the existing literature, it can be found that the method of subjective model analysis is applied to most current studies and the selection of model indexes and the determination of index weights differ largely from each other. Therefore the result of previous studies lacks reliability and is less convincing. In this study, the widely used two-phase analysis method is adopted in related studies. In Phase I, the output-oriented CCR Model from DEA (Data Envelopment Analysis) method is used in order to measure the overall efficiency of rural informatization; in Phase II, Tobit regression model is used in order to empirically test the influencing factors of developmental efficiency of rural informatization and to carry out a systematic analysis.

目前中国农村信息化研究大致可分为以下几个方面：一是关于农村信息化发展对策建议的理论研究。这方面研究的内容涉及农村信息化发展政策体系的完善（杨诚，2009）[13]，农村信息化产品市场发展政策（马明远等，2009）[9]等；二是关于中国与国外农村信息化的比较研究，讨论国外农村信息化建设的经验与教训，探讨在中国农村信息化建设过程中的可资借鉴之处（贺洪明等，2011）[2]；三是关于农村信息化发展的具体技术框架及方案，讨论农村信息化平台建设（周卫，2011）[14]等等，这部分研究技术色彩较重，文献数量不多；四是对农村信息化建设状况进行评估研究。随着农村信息化建设的深入，此方面的研究文献在最近几年开始增加，其中大多数研究限于讨论农村信息化评价指标体系并在此基础上进行不同地区信息化发展水平的比较（周跃锋等，2010）[15]，只有少数研究同时进行了影响信息化发展因素的分析，具体分析方法包括回归分析法（刘春年等，2006）[6]，灰关联分析法（王爽英，2008）[12]，因子分析法（赵晖等，2010）[16]等。其他关于农村信息化的研究是把农村信息化作为社会经济现象，讨论它与其他社会经济现象之间的关联关系，如农村信息化与农户收入的关系（曾硕勋等，2010）[17]，农村信息化与经济发展的关系（黄志文，2010）[3]，农村信息化对农民生计改善的影响（张莉等，2011）[18]等等。

本文的研究可归为上述第四个方面，分析现有文献发现，现有研究大多采用的是主观模型分析方法，模型指标的选择和指标权重的确定都存在较大差异，研究结论存在可信度和说服力的欠缺。本文拟采用成熟的 DEA-Tobit 两阶段分析方法进行相关研究，第一阶段首先利用 DEA（Data Envelopment Analysis，数据包络分析）方法中产出导向的 CCR 模型测算农村信息化发展整体效率，第二阶段应用 Tobit 回归模型，实证检验影响农村信息化发展效率的因素并进行系统的分析。

METHODS AND MATERIALS

Research methods and index data

The DEA method is a nonparametric evaluating method that uses a mathematical programming model to measure the relative efficiency of DMUs (Decision Making Units) in multi-input and multi-output situations. By observing numerous and practical production data, we construct a relatively effective frontier efficiency surface, and then calculate efficiency level of the preset DMU relative to the efficiency level on the efficiency surface, i.e., the preset DMU's relative efficiency value. As a nonparametric method, the DEA method neither needs specific production function specifying its input and output, nor considering the efficiency of parameter estimation and reasonable inspection. This method has an advantage when evaluating the efficiency of DEA in complicated productive relations. Moreover, in the DEA model, the input and output variables' weights are produced by mathematical programming precisely according to practical data, the result of which cannot be affected by human factors. Therefore, the DEA method is often applied to studies of developmental efficiency of rural informatization, and furthermore it has advantages over most current methods.

By analyzing slack variables of input and output, the DEA method could determine the degree of the effect of the input and output factors on its efficiency and improvement approaches. However, with regard to factors that are not appropriate as input and output indexes, but that have objectively affected DMU efficiency, the DEA method could not directly analyze the effects of these factors on efficiency. Therefore, on the basis of the DEA method, a two-phase method is developed. In Phase I, the relative efficiency value of DMU is calculated by the DEA model. In Phase II a regression model is constructed to analyze data with the efficiency value obtained in Phase I as an explained variable and influencing factor on external environment as an explanatory variable. Due to the fact that the efficiency value calculated by the usual DEA method is between 0 and 1 (maximum 1), the explained variable of the regression equation in Phase II is restricted to this interval. Since it has a censored feature, Tobit regression model is usually selected.

The DEA-Tobit two-phase method is a mature approach when analyzing efficiency and influencing factors. But it is not applied in studies of Chinese rural informatization. So in this paper, the method is employed to study Chinese rural informatization development so as to improve current methods and compensate for present deficiencies.

According to the DEA-Tobit two-phase requirement, corresponding indexes are selected for different phases. Rural informatization could be regarded as a productive system, in which the investment in certain production resources should lead to corresponding economic and social output. Therefore, in the analysis phase of DEA, output and input indexes are usually selected. With present research achievements and informatization development index of the International Telecommunication Union as references, DEA indexes for this study are selected. See Table 2.

研究方法与材料

研究方法与指标数据

DEA 方法是一种利用数学规划模型在多投入多产出情况下测算 DMU（Decision Making Units，决策单元）相对效率的非参数评估方法，通过观测到的大量生产实践数据，构建出相对有效的前沿效率面，然后计算出某个给定 DMU 相对于那些处于效率面的 DMU 的效率水平，即该给定 DMU 的相对效率值。作为一种非参数方法，DEA 方法不需要指定投入产出的具体生产函数形态，也不需要考虑参数估计的有效性和合理性检验方面的问题，在评价具有非常复杂生产关系的决策单元的效率时具有优势，DEA 模型中投入、产出变量的权重由数学规划严格根据实际数据产生，不存在人为因素的影响。可见，DEA 方法不仅适用于研究农村信息化发展效率，而且相对目前大多数研究采用的方法具有优势。

DEA 方法可以进一步通过投入产出数据的差额变量分析，确定投入产出因素对效率的影响程度及改进途径，但对于某些不适合作为投入产出指标却客观影响 DMU 效率的因素，DEA 方法不能直接分析这些因素对效率的影响，因此在 DEA 方法的基础上发展出现了“两阶段法”，该方法第一阶段先通过 DEA 模型测算出 DMU 的相对效率值，第二阶段以第一阶段得到的效率值作为被解释变量，以外部环境影响因素等作为解释变量建立回归模型进行分析。由于常见的 DEA 方法测算出来的效率值都处于 0 和 1 之间，最大值为 1，第二阶段回归方程的被解释变量就被限制在这个区间，具有截断（censored）特征，因此通常选择 Tobit 回归模型。

DEA-Tobit 两阶段法分析效率及其影响因素是成熟的分析方法，但在涉及中国农村信息化的研究中尚未得到应用。本文拟将该方法引入中国农村信息化发展研究，以改善研究方法，弥补现有研究中存在的不足。

根据 DEA-Tobit 两阶段研究需要，本文按照不同阶段的要求选择相应的指标项。农村信息化可以视为一个生产系统，投入一定的生产性资源要素带来相应的经济和社会产出，因此在 DEA 分析阶段，选择的是具有投入产出性质的指标，在参考借鉴了现有研究成果以及国际电信联盟信息化发展指数基础上，研究选择的 DEA 指标见表 2。

Table 2

The input and output indexes of DEA analysis

Index Category	Index Name
`Input Index	Consumption levels of rural residents in different regions
	Average living consumption of a rural family (transportation, communication, cultural and educational entertainment products and services) in different regions
	Employment numbers in telecommunication industry and other service industries of information transmission
	Expenditure on education, culture, media and finance in different regions

Output Index	Total investment in fixed assets of information transmission, computer services and software industry in different regions
	Average number of televisions by every 100 rural households in different regions
	Average number of home computers by every 100 rural households in different regions
	Average number of telephone s by every 100 rural households in different regions

In Tobit analysis, economic and social factors that affect developmental efficiency of rural informatization are of great concern. The World Bank has reported that the development of Chinese rural informatization mainly depends on the construction of informatization projects conducted and participated in by government and telecommunication enterprises. Thus, the paper put forward the following assumptions. The first is the assumption that various overall construction projects are important influencing factors in determining developmental efficiency of rural informatization. As there are no fundamental differences between these construction projects in different regions, they can be grouped as a comprehensive influencing factor, which is represented by a constant term in Tobit Model. The second is the assumption that the difference in developmental efficiency in different regions is mainly affected by rural informatization consumption and regional levels in economic development. Specific indexes and descriptions of corresponding theoretical assumption are shown in Table 3.

在 Tobit 分析阶段，研究关注的是哪些经济社会因素影响着农村信息化的发展效率。根据世界银行的研究报告，中国农村信息化的发展，主要是依靠一系列中央政府和基础电信企业主导和参与的信息化项目的建设。据此本文提出以下假设：假设各种全局性项目建设是决定农村信息化发展效率的重要影响因素，由于这些项目建设不存在地区之间的根本性差异，因此归纳为一个综合性影响因素，通过 Tobit 模型中的常数项表示；假设地区之间的发展效率差异，主要受农村信息化消费和地区经济发展水平影响，具体指标和相应的理论假设描述见表 3。

Table 3

Explanatory variable indexes of Tobit regression analysis

Index	Assumption
Total dependency proportion of rural population	Rural population age structure is related to developmental efficiency of rural informatization
Proportion of education level (junior high schools and below) of labor force in rural households	Education level is related to developmental efficiency of rural informatization
Final consumption expenditure of rural residents	Consumption ability of informatization is related to developmental efficiency of rural informatization
Proportion of the primary industry's employment in all employments	Economic development level is related to developmental efficiency of rural informatization
Proportion of primary industry's total output value in regional total output value	

According to the assumptions above, an empirical Tobit regression model is established as follows:

根据以上假设确定实证 Tobit 回归模型如下：

$$Y_{it} = \beta_0 + \beta_1 DR_{it} + \beta_2 EDU_{it} + \beta_3 Ln(CE_{it}) + \beta_4 EP_{it} + \beta_5 VA_{it} + \varepsilon_{it} \quad (1)$$

In this model, *t* represents Year; *i* represents DMU; Y_{it}, the overall relative efficiency value of different regions and years in Phase I; DR_{it}, the total dependency proportion of rural population; EDU_{it}, the Proportion of education level; CE_{it}, final consumption expenditure; EP_{it}, proportion of primary industry employment in all employment; VA_{it}, proportion of primary industry's employment in all employments; β_1 to β_5 are regression coefficients of corresponding explanatory variables; β_0, a constant term; ε_{it}, a residual term. A logarithmic transformation of rural residents' final consumption expenditure index data is conducted to facilitate the explanation of model measurement results and to ensure a good fit.

The study is based on public data, all of which have been collected from *China Statistical Yearbook, China*

其中，*t* 表示年份，*i* 表示 DMU，Y_{it} 为第一阶段得到的各地区各年整体相对效率值，DR_{it} 为农村人口总抚养比，EDU_{it} 为文化程度比重，CE_{it} 为最终消费支出，EP_{it} 为第一产业人员占就业人员比重，VA_{it} 为第一产业增加值占地区生产总值比重，β_1 至 β_5 为相应解释变量的回归系数，β_0 为常数项，ε_{it} 为残差项。为方便解释模型计量结果及保证拟合优度，对农村居民最终消费支出指标数据进行了对数转换。

研究基于公开数据进行，所有数据收集自《中国统计年鉴》、《中国农村统计年鉴》、《中国城市统计年鉴》、

Rural Statistical Yearbook, China City Statistical Yearbook, China Population and Employment Statistical Yearbook and *China Information Yearbook*. Part of the data is from province and city statistical yearbooks and the survey report of rural internet development from China Internet Network Information Center.

《中国人口和就业统计年鉴》和《中国信息年鉴》，部分数据来自各省市统计年鉴和中国互联网络信息中心农村互联网发展状况调查报告。

RESULTS ANALYSIS AND DISCUSSIONS

Empirical analysis

1) DEA analysis: study of the overall efficiency of rural informatization development

In this paper, the provincial administrative region is taken as the DMU of DEA analysis. Due to the restriction of data availability and integrity, Tibet, Taiwan, Hong Kong and Macao are not included.

Different DEA models can measure and decompose different relative efficiencies. However, this paper only involves the overall relative efficiency of rural informatization development, which can be obtained by CCR model. For now, the development strategy of urban-rural integration has been determined, but there are still big differences between rural and urban informatization both now and in the future. So the key to studies of rural informatization development is to improve output ability as much as possible under the constraints of fixed resources or in the situation of maintaining the present input level and environment; thus an output-oriented model is adopted.

结果分析与讨论

实证分析

1)DEA 分析：农村信息化发展整体效率研究

本文将省级行政区作为 DEA 分析的 DMU，受数据可得性和完整性限制，研究不包括西藏、台湾、香港和澳门地区。

不同的 DEA 模型能够测算分解出不同的相对效率，而本文研究只涉及农村信息化发展的整体相对效率，通过 CCR 模型就可以直接得到。同时，在城乡一体化发展战略已经确定，而城乡信息化差距仍然较大的现实状况下，现阶段乃至今后相当长的一段时期，研究农村信息化发展首要是关注在既定的资源约束条件下，或在维持现有水平的投入和环境的情况下，尽可能提高产出水平，因而模型采用产出导向形式。

Table 4

The overall developmental efficiencies of China rural informatization in different regions during 2007-2010

DMU		2007	2008	2009	2010	DMU		2007	2008	2009	2010
East	Beijing	1	1	1	1	West	Inner Mongolia	0.6541	0.6515	0.6290	0.6344
	Tianjin	1	1	0.9610	0.9676		Guangxi	1	0.9805	1	1
	Hebei	0.8270	0.8852	1	1		Chongqing	1	0.9128	0.8835	0.9482
	Shanghai	1	1	1	1		Sichuan	1	1	0.9133	0.8689
	Jiangsu	0.9436	0.6522	0.6062	0.5976		Guizhou	1	1	1	0.9875
	Zhejiang	0.8850	0.9631	1	0.9752		Yunnan	0.8047	0.8772	0.8162	0.8211
	Fujian	1	1	1	1		Shaanxi	1	1	1	0.9801
	Shandong	0.7364	0.7435	0.7905	0.9198		Gansu	1	1	1	1
	Guangdong	1	1	1	1		Qinghai	1	1	1	1
	Hainan	1	0.9375	0.9272	0.9502		Ningxia	1	1	1	1
Average value		0.9392	0.9181	0.9285	0.9410		Xinjiang	0.8835	0.8614	0.8641	0.8301
Standard deviation		0.0936	0.1239	0.1311	0.1237	Average value		0.9402	0.9349	0.9187	0.9155
Middle	Shanxi	0.8888	0.8797	0.8943	0.8424	Standard deviation		0.1149	0.1082	0.1176	0.1168
	Anhui	0.9373	0.9235	0.8396	0.8818	Northwest	Liaoning	0.7823	0.7427	0.6883	0.7131
	Jiangxi	0.9089	0.8321	0.9136	0.8934		Jilin	0.8895	0.8453	0.7861	0.7835
	Henan	0.9205	0.8938	0.8903	0.8905		Heilongjiang	0.9040	0.8409	0.8520	0.9169
	Hubei	0.8692	0.8569	0.9142	0.9544	Average value		0.8586	0.8096	0.7755	0.8045
	Hunan	0.7051	0.7062	0.7221	0.7363	Standard deviation		0.0665	0.0580	0.0824	0.1035
Average value		0.8716	0.8487	0.8624	0.8665						
Deviation		0.0850	0.0765	0.0739	0.0732						

It can be seen in DEA analysis that developmental efficiencies of rural informatization in the middle and northeast regions are lower than that of the east and west regions. Observation of standard deviations of the developmental efficiency in different provinces and cities also finds that rural informatization of provinces and cities in the middle regions is close to that of the northeast

DEA 分析发现，中部和东北地区的农村信息化发展效率低于东部和西部地区。观察各区域内不同省区市之间发展效率的标准差，又可以发现中部和东北地区各省区市农村信息化发展效率较为接近，差异程度小于东部和西部地区

regions, and its difference is lower than that of provinces and cities in the east and west regions.

The Kruskal-Wallis Regional Difference Test is conducted to learn China's developmental efficiency of rural informatization in different regions. However, the data need to be regrouped to avoid a distortion of results due to insufficient sample sizes of a group. China has successively developed and strengthened its macro development strategies in different regions, e.g., East Open, West Development, Northeast Promote and Rising of Central China. The strategies and corresponding preferential policies, project construction as well as domestic and foreign investment promotion are the main reasons for social and economic development in different regions. Since 2005, divisions of Chinese economic regions in national statistics have been consistent with the divisions determined by the above strategies. In view of the actual influence of regional development strategies and the economic development levels in other provinces and cities, this paper incorporates the northeast region into the middle; and then conducts a difference test according to trichotomy of dividing the country to the east, the middle and the west.

各省区市的差异程度。

进一步对中国不同区域农村信息化发展效率进行 Kruskal-Wallis 区域差异性检验。为避免分组样本容量不足导致检验结果失真，需要进行重新分组处理。中国先后确立实施了东部开放、西部开发、振兴东北和中部崛起的宏观区域发展战略，实践中这些战略及其相应的优惠政策、项目建设以及所带动国内外投资是决定区域社会经济发展的主要原因，自 2005 年起，国家统计资料中对中国经济区域的划分开始与以上战略所确定的区域划分保持一致。从区域发展战略实际影响的角度考虑，同时参考各省市经济发展水平，本文将东北地区并入中部地区，按照东部、中部和西部三分法划分全国区域进行差异性检验。

Table 5

An investigation of regional differences in Chinese developmental efficiency of rural informatization

Regional comparison	2007	2008	2009	2010
East-Middle	3.962(0.0465)**	4.947(0.0261)**	6.190(0.0128)**	7.844(0.0051)***
East-West	0.113(0.7372)	0.023(0.8791)	0.097(0.7549)	0.436(0.5093)
Middle-West	4.659(0.0309)**	6.653(0.0099)***	3.558(0.0592)*	2.944(0.0862)*
East-Middle-West	6.100(0.0474)**	7.920(0.0191)**	6.667(0.0357)**	7.373(0.0251)**

Notes: *, ** and *** represent 10%, 5%, and 1% significance levels of statistics respectively; the number in brackets is the p value.

At the national level, the investigation shows that differences are significant at the 5% level regarding the three regions' developmental efficiency of rural informatization. Further studies of differences show that there are significant differences between the west and the middle, the east and the middle regarding their developmental efficiencies. It can't be denied that there is no significant difference between the developmental efficiency of the east and west regions. In light of the relative average efficiency value of different regional development (Table 5), it is clear that the phenomenon of "central China subsidence" still exists in rural informatization development in 2007-2010.

在全国意义上，检验证明三个区域农村信息化发展效率的差异性在 5%水平上是显著的。继续进行两两差异性检验，结果发现，西部和中部，东部和中部发展效率都存在显著差异，东部和西部之间的发展效率，都不能拒绝二者无显著差异的假设。联系表 5 中不同区域发展相对效率均值的大小，可以发现，2007-2010 年期间，"中部塌陷"现象在农村信息化发展中也同样有所表现。

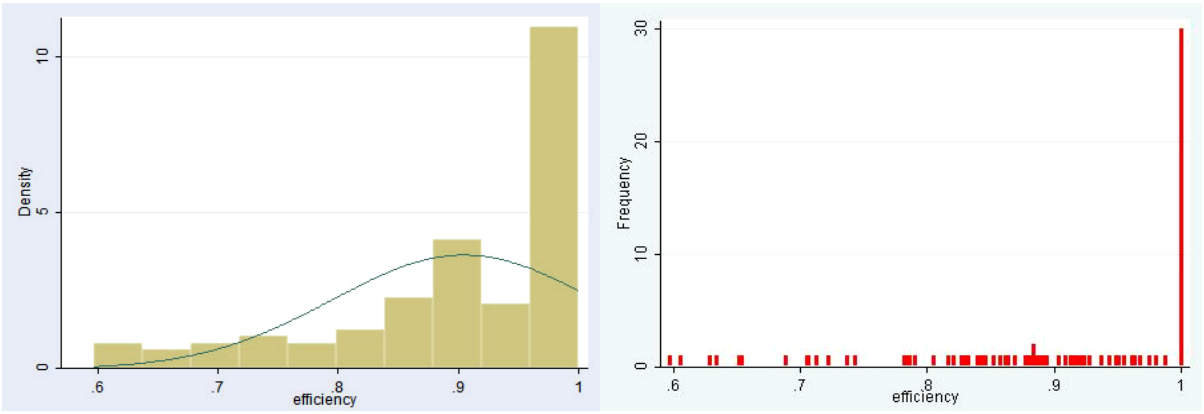

Fig.1 - Distribution and discrete option of developmental efficiency

2) Tobit regression analysis: the influencing factor analysis of developmental efficiency of rural informatization

This paper uses stata12.0 to carry out regression analysis and estimation.

Figure 1 depicts the distribution and discrete option of developmental efficiency of rural informatization. We can see the censoring in the data, because the efficiency values are bounded to the interval [0, 1]. In the right of discrete option, the spike is the frequencies for cases where efficiency=1. The relationship between developmental efficiency with explanatory variables is shown in Figure 2. The total dependency proportion of rural population seems to present a positive correlation with efficiency and other variables present a negative correlation.

Two indexes, i.e., the proportion of primary industry's employment in all employments and proportion of primary industry's total output value in regional total output value are similar indexes that reflect development level of economy. Although they can be used as explanatory variables for now, these two indexes cannot pass a multi-co-linearity examination. Therefore a different model is used for analysis. Regression results are shown in Models 1 and 2, Table 6. Model 3 is the regression results of the effects of rural informatization consumption factors on its developmental efficiency.

2) Tobit 回归分析：农村信息化发展效率影响因素分析

本研究运用 stata12.0 软件对模型及其统计数据进行回归分析和估计。

图 1 描述了农村信息化发展效率的分布和离散项，由于效率值被界定在 0 和 1 之间，可以看出数据截断的情况。在离散项最右边的那条竖线，是效率值等于 1 时的频数。图 2 反映的是发展效率与其他解释变量之间的关系。农村人口总抚养比与发展效率似乎呈正相关关系，其他变量则呈负相关关系。

第一产业就业人员占就业人员比重和第一产业生产总值占地区生产总值比重这两个指标，是反映经济发展水平的同类指标，这两个指标同时作为解释变量时不能通过多重共线性检验，因此使用不同模型进行分析，回归结果见表 6 中的模型 1 和模型 2。模型 3 是仅考察农村信息化消费因素对农村信息化发展效率影响的回归结果。

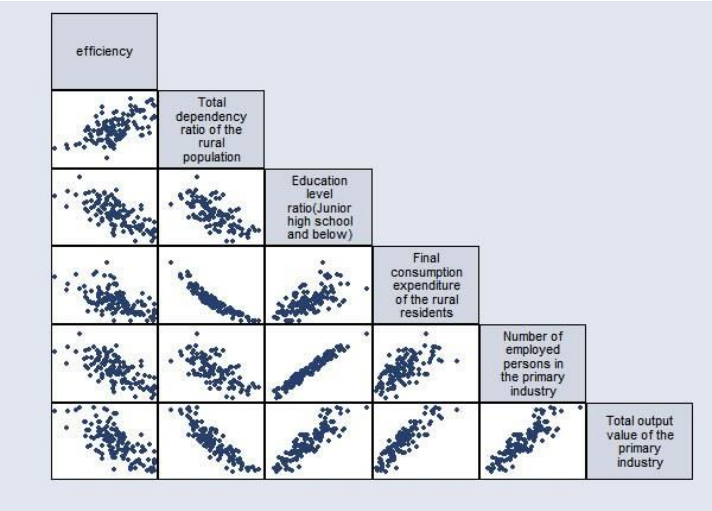

Fig.2 - The relationship between pairs of the six variables

Table 6

Tobit regression results of influencing factors on developmental efficiency of rural informatization

Explaining variable	Model 1	Model 2	Model 3
Total dependency proportion of rural population	1.358***	1.252***	1.002***
	(0.263)	(0.243)	(0.235)
Proportion of education level (Junior high school and below)	-0.950***	-0.638**	-1.152***
	(0.281)	(0.313)	(0.278)
Final consumption expenditure of the rural residents	-0.0873***	-0.0860***	-0.0840***
	(0.0170)	(0.0166)	(0.0168)
Proportion of the employed in primary industry		-0.432***	
		(0.145)	
Total output value of the primary industry	-0.884***		
	(0.296)		
Constant term	1.927***	1.759***	2.095***
	(0.261)	(0.270)	(0.257)
Sigma	0.129***	0.127***	0.133***

Explaining variable	Model 1	Model 2	Model 3
	(0.0113)	(0.0112)	(0.0117)
VIF average value	1.68	1.96	1.46
Log likelihood	18.63	18.47	14.14
LR chi2	52.52	52.19	43.53
Prob > chi2	1.08e-10	1.26e-10	1.90e-09
Pseudo R-squared	3.444	3.423	2.855

Notes: *, ** and *** represent 10%, 5% and 1% significance levels of statistics respectively; the number in brackets is the standard deviation.

In this paper, the proposed theoretical assumptions that the rural population age structure, education level of rural households, consumption ability and development level of economy are related to developmental efficiency of rural informatization are strongly supported by regression results and mainly stay at the 1% level which is statistically significant. The total dependency proportion of rural population and constant term present a positive correlation with developmental efficiency of rural informatization, whereas proportion of education level (Junior high school and below), final consumption expenditure of rural residents and proportion of the employed in the primary industry present a negative correlation with the total output value of the primary industry.

When comparing Models 1 and 2, it is found that as two indexes to measure regional economic development level, the proportion of the employed in the primary industry leads to less loss that affects developmental efficiency of rural informatization than that of the total output value of the primary industry. Moreover, the overall variation degree is much smaller whilst its reliability as an explanatory factor is bigger.

本文所作的农村人口年龄结构、农村居民家庭劳动力文化程度、消费能力、经济发展水平与农村信息化发展效率相关的理论假设，都得到了模型回归结果的稳健支持，并且基本上都在 1%水平上统计显著。其中，农村人口总抚养比和常数项与农村信息化发展效率呈现正相关关系，文化程度比重（初中及以下）、农村居民最终消费支出、第一产业就业人员比重和第一产业生产总值比重则呈现负相关关系。

比较模型 1 和模型 2 发现，作为衡量地区经济发展水平的两个指标，第一产业就业人员比重相对于第一产业生产总值比重，前者对导致农村信息化发展效率损失的影响程度要小于后者，并且总体上变异程度更小，解释可靠性更大。

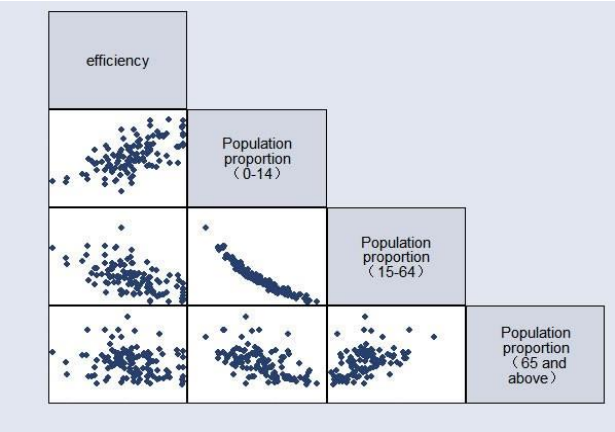

Fig.3 - The relationship between pairs of the efficiency and the structure of population age

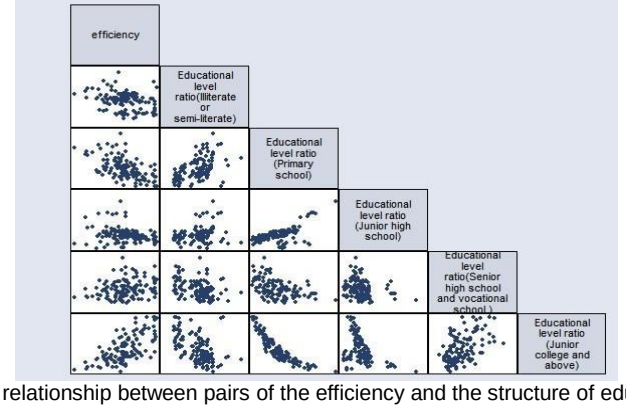

Fig.4 - The relationship between pairs of the efficiency and the structure of education level

From Figure 3 and 4, we can see the different structure of population age seems to have influence on developmental efficiency, the same as the structure of education level. Thus, based on the regression analysis in Table 6, and in order to further study the effects of consumption on developmental efficiency of rural informatization, a further regression analysis is carried out which decomposes the total dependency proportion of rural population and education level indexes. The results are shown in Tables 7 and 8 respectively.

通过图 3 和 4，我们发现不同的年龄结构和教育程度对于发展效率均会产生一定的影响。因此，为更深入研究消费因素对农村信息化发展效率的影响，在表 6 回归分析的基础上，进一步分解了农村人口总抚养比和文化程度比重指标进行回归分析，结果分别见表 7 和表 8。

Table 7

Tobit regression results of the effects of rural population's age structure on developmental efficiency of rural informatization

Explaining variable	Model 1	Model 2	Model 3	Model 4	Model 5	Model 6
Proportion of education level (Junior high school and below)	-1.305***	-1.091***	-0.637**	-0.726**	-0.650**	-0.443
	(0.278)	(0.267)	(0.283)	(0.299)	(0.314)	(0.344)
Final consumption expenditure of rural resident	-0.0687***	-0.0864***	-0.0827***	-0.0668***	-0.0882***	-0.0801***
	(0.0164)	(0.0168)	(0.0202)	(0.0160)	(0.0168)	(0.0203)
Proportion of the employed in primary industry				-0.521***	-0.338**	-0.155
				(0.145)	(0.140)	(0.160)
Population proportion from 0-14 years old	1.773***			2.326***		
	(0.367)			(0.388)		
Population proportion of 15-64 years old		-1.677***			-1.877***	
		(0.354)			(0.358)	
Population proportion of 65 years old and above			0.278			-0.0153
			(0.864)			(0.910)
Constant term	2.158***	3.637***	1.996***	1.766***	3.558***	1.905***
	(0.247)	(0.445)	(0.292)	(0.251)	(0.436)	(0.305)
Sigma	0.130***	0.131***	0.146***	0.122***	0.128***	0.145***
	(0.0114)	(0.0115)	(0.0129)	(0.0106)	(0.0111)	(0.0129)
VIF average value	1.63	1.39	1.32	2.14	1.82	1.78
Log likelihood	16.59	16.25	5.339	22.97	19.14	5.803
LR chi2	48.42	47.75	25.93	61.19	53.54	26.85
Prob > chi2	1.73e-10	2.40e-10	9.88e-06	0	6.58e-11	2.13e-05
Pseudo R-squared	3.175	3.132	1.700	4.013	3.511	1.761

Notes: *, ** and *** represent 10%, 5% and 1% significance levels of statistics respectively; the number in brackets is the standard deviation.

In Table 7, the results in Models 4, 5, 6 and those in Models 1, 2, 3 can verify each other, and the six models have verified the regression results of the proportion of education level (Junior high school and below), final consumption expenditure of rural residents, proportion of the employed in primary industry and the constant term in Table 6. Further analysis of the consumption population's age structure finds that the population proportion from 0-14 years old presents a positive correlation with developmental efficiency of rural informatization, whereas the population proportion from 15-64 years old presents a negative correlation. Both indexes are statistically significant at the 1% level; however statistic verification of population proportion of 65 years old and above is not statistically significant in Model 3 and 6. Moreover the goodness of fit in Models 3 and 6 is obviously lower than that of other models.

表 7 中的模型，模型 4、5、6 与模型 1、2、3 的结果可以互相验证，同时这 6 个模型又验证了表 6 中模型对文化程度比重（初中及以下）、农村居民最终消费支出、第一产业就业人员比重和常数项的回归结果。对消费人口年龄结构的更深入分析发现，0-14 岁人口比重与农村信息化发展效率呈现正相关，15-64 岁人口比重与农村信息化发展效率呈现负相关，这两个指标都在 1%水平上统计显著，而 65 岁及以上人口比重指标的统计检验在模型 3、6 中均不显著，并且模型 3、6 的拟合优度明显低于其他模型。

Table 8

Tobit regression results of the effects by education level on developmental efficiency of rural informatization

Explaining variable	Model 1	Model 2	Model 3	Model 4	Model 5
Proportion of population independency	0.267	0.826***	0.285	0.891***	1.036***
	(0.268)	(0.247)	(0.243)	(0.230)	(0.248)
Final consumption expenditure of rural residents	-0.0705***	-0.0855***	-0.0684***	-0.0858***	-0.0759***
	(0.0188)	(0.0175)	(0.0186)	(0.0169)	(0.0172)
Proportion of education level (Illiterate or semi-literate)	0.621				
	(0.439)				
Proportion of education level (Primary school)		-0.562**			
		(0.215)			
Proportion of education level (Junior high school)			-0.437*		
			(0.231)		
Proportion of education level (Senior high school and vocational school)				1.351***	
				(0.346)	
Proportion of education level (Junior college and above)					3.563***
					(1.097)
Constant term	1.277***	1.349***	1.522***	0.992***	0.993***
	(0.137)	(0.136)	(0.191)	(0.143)	(0.142)
sigma	0.144***	0.139***	0.144***	0.135***	0.136***
	(0.0128)	(0.0123)	(0.0128)	(0.0119)	(0.0119)
VIF average value	1.49	1.43	1.32	1.41	1.42
Log likelihood	5.307	7.626	6.099	12.09	13.37
LR chi2	25.86	30.50	27.45	39.43	41.98
Prob > chi2	1.02e-05	1.08e-06	4.75e-06	1.41e-08	4.05e-09
Pseudo R-squared	1.696	2.000	1.800	2.586	2.753

Notes: *, ** and *** represent 10%, 5% and 1% significance levels of statistics respectively; the number in brackets is the standard deviation.

Likewise, the regression results in Table 8 and those in Table 6 and 7 can verify each other. The results of the final consumption expenditure of rural residents and the constant term are highly consistent with each other. The regression results of different education levels show that, apart from the statistic non-significance at the illiterate and semi-literate education levels, education levels at 5% and 10% significance levels in primary schools and junior high schools retain a negative correlation with developmental efficiency of rural informatization. Senior high school, vocational school, junior college and above at the 1% significance level retains a positive correlation.

In the analysis of Tobit regression results, it can be seen that in all models the constant term passed the statistically significant verification at the 1% significance level. Further comparison of regression coefficients in various models shows that the constant term has the greatest influence on developmental efficiency of rural informatization. According to the theoretical assumptions above, the regression results show that with the macro policies aimed at strengthening agriculture and benefiting farmers during 2007-2010, various overall rural informatization development projects focused in infrastructure construction have been the main influencing factors in improving the overall developmental efficiency of rural informatization. About the development modes of China's rural informatization, the World Bank research report (2009) holds that the mode dominated by the Chinese central government has obvious and practical advantages and a promotional value in future.

表 8 中的模型回归结果同样能够与表 6 和表 7 中各模型结果互相验证，特别是对农村居民最终消费支出和常数项的结果高度一致。对不同文化程度分别回归的结果显示，除不识字或识字很少文化程度的统计不显著以外，小学、中学文化程度在 5%和 10%显著水平上与农村信息化发展效率呈现负相关，而高中和中专、大专及以上文化程度在 1%水平上与农村信息化发展效率呈现正相关。

分析以上 Tobit 回归结果，首先注意到在所有模型中，常数项均以 1%的水平通过统计显著性检验，进一步比较各模型中的回归系数，常数项对农村信息化发展效率值的影响也是最大的。按照前述理论假设，回归结果表明：2007-2010 年间，在中国惠农强农的宏观政策环境下，各种全局性的、主要集中在基础设施建设方面的农村信息化建设发展项目，是推动农村信息化整体发展效率提升的主要影响因素。世界银行研究报告（2009 年）在对中国农村信息化发展模式的分析研究中，认为中央政府主导模式具有明显实践优势和未来推广价值，与本文此处的研究结论

The result can be verified by the result of this paper in this part.

Urbanization and industrialization would lead to inevitable loss of social and economic resources in rural areas. Although the present policies and measures set by non-market systems compensate for resource loss, the overall efficiency loss of resource allocation is inevitable. Research shows that the level of regional economic development presents a significantly negative correlation with the overall developmental efficiency of rural informatization. Since Chinese urbanization is generally lagging behind industrialization, the extent of influence that regional urbanization and industrialization have on the overall developmental efficiency of rural informatization also differs. The regression results show that relatively hysteretic urbanization avoids the rapid decline in rural population, thus stabilizing the number of consumption population of rural informatization. Under the condition of a vigorous national construction of infrastructure projects related to rural informatization, a quantitative balance between consumption and production could alleviate to a certain extent the negative effects by rural social and economic resource loss.

The rural residents' final consumption expenditure has a significantly negative correlation with developmental efficiency of rural informatization. During 2007-2010, the rural per capita net income and per capita annual living expenditure have increased by 12.69% and 10.79% respectively. About the expenditure constitution, consumption is inclined to be more material-oriented than spirit-oriented. Material consumption, represented by housing and household facilities, keeps increasing in absolute amount and in the proportion of all consumption. However, spiritual consumption, represented by cultural, educational and entertainment products and services, accounts for a smaller proportion of expenditure, and this trend continues to decrease. This indicates that the consumption structure of a Chinese rural resident is still at a low stage and is characterized by meeting basic needs, with food and shelter accounting for the most shares. In addition the infrastructure construction for rural informatization is still weak with insufficient basic services. Rural residents lack knowledge and skills of how to apply informatization. Inappropriate ideas and understanding, the unchanged traditional consumption structure, consumption custom and consumption mode all lead to insufficient informatization consumption.

The rural population structure correlates with the overall efficiency of informatization development. From the perspective of the population age structure, a large rural population outflow for work in urban areas aggravates the issues of the left-behind children and population aging. However, the demand of migrant workers contacting their hometown increases the demand of rural informatization consumption, which is a reasonable explanation for the regression results. From the perspective of the education level, the higher the education level is, the more it contributes to the developmental efficiency of rural informatization. The proportions of education levels at senior high school, vocational school and above are important factors of improving efficiency. Based on the common understanding that education level not only affects income but also influences consumption expenditure and structure, this paper assumes that a higher education level contributes to improving informatization consumption level and optimizing consumption structure appropriately, thus can improve the overall developmental efficiency of rural informatization.

可以相互验证。

城市化和工业化必然带来农村社会经济资源的流失，虽然现有的各种非市场制度安排的政策措施对资源流失起到了补偿作用，但整体上出现资源配置效率损失是难免的，研究表明区域经济发展水平与农村信息化整体发展效率之间呈现显著负相关性。由于中国城市化普遍滞后于工业化，区域城市化和工业化水平对农村信息化整体发展效率的影响程度应存在差异，分析回归结果发现：城市化相对滞后，从另一角度看是避免了农村人口数量的快速下降，从而稳定了农村信息化的消费人口数量，在国家大力建设农村信息化基础设施的情形下，保持消费与生产之间数量上的相对平衡，在一定程度上缓解了农村社会经济资源流失产生的负面效应。

农村居民最终消费支出与农村信息化发展效率之间具有显著负相关性。2007-2010 年，农村居民人均纯收入和人均生活消费支出年均增速分别达到了 12.69%和 10.79%，从消费支出构成看，消费偏重于物质性消费，精神性消费少，以住房和家庭设备用品为代表的物质消费，在绝对量和所占消费支出的比重都呈增长趋势，文教娱乐用品及服务支出为代表的精神性消费不仅比重小，而且呈下降趋势，说明总体上中国农民的消费结构基本上仍然处于低级阶段，特征是满足基本生存需求，吃和住占主要份额。此外，农村信息化基础建设仍然比较薄弱，基础服务匮乏，农村居民信息化应用知识和技能欠缺，观念和认知偏差，变化不大的传统消费结构、消费习惯和消费模式等也造成信息化消费不足。

农村人口结构与信息化发展整体效率之间存在相关性。从人口年龄结构来看，农村劳动年龄人口的大量外出务工流出，加重了农村留守儿童和老龄化问题，外出务工人员与家乡之间的联系需要增加了农村信息化消费需求，这应该是对回归结果的一个合理解释；从文化程度结构来看，文化程度越高则对农村信息化发展效率的贡献程度就越大，其中高中和中专及以上文化程度比重是发展效率改善提高的显著因素，本文认为，基于文化程度不仅影响收入水平，而且影响消费支出和消费结构的普遍认知，较高的文化程度有助于提高信息化消费水平、合理优化消费结构，从而改善农村信息化整体发展效率。

CONCLUSIONS

Evaluation on the developmental efficiency of rural informatization is of great importance for improving the overall informatization level and optimizing the informatization input structure. In this paper, a CCR model of DEA is used to measure the developmental efficiency of Chinese rural informatization during 2007-2010. The results show that the developmental efficiencies in the middle and northeast regions are lower than those in the east and west regions. The Kruskal-Wallis difference investigation also indicates that there are significant differences of developmental efficiency between the east and west regions, and between the east and middle regions. The phenomenon of "central China subsidence" is clearly manifested in rural informatization. A Tobit analysis shows that the construction projects of rural informatization are the main influencing factor improving the overall developmental efficiency. Both the developmental level of regional economy and the final expenditure output of rural residents have negative correlation with the developmental efficiency of rural informatization. The structure of population age, the structure of education level and the overall developmental efficiency of informatization are all correlated with one another.

With regard to the strategies that could improve the developmental efficiency of rural informatization, one is to increase the overall construction of rural informatization infrastructure; the other is to supplement local projects according to different development levels in various regions. The construction of rural informatization conducted by the central government is the main reason for the great achievements in a short period. However, rural informatization is a complicated and comprehensive social project, and construction of infrastructure like information facilities and information services, is just one part of it. Therefore, a long-term development should be based on a sound market for rural informatization. Thus, to guarantee a healthy development of rural informatization, we should encourage a shift away from policy support to development of market consumption, enhance the level of rural informatization consumption and optimize the structure of consumption.

The methods used in this paper have great significance and implications for future studies of developmental efficiency of rural informatization in similar areas; however there is still room for further improvements and discussion on the study. For example, there are certain controversies over the selection of model variable indexes in the DEA analysis phases, and controversies over whether the index of education level and the variable index of information industry macro contribution should be included in evaluating informatization levels. Moreover, in the Tobit analysis phase, in light of the consumption environment and external macro development environment, certain representative influencing factors are selected in this paper, and the effects of the overall and regional factors on rural informatization are decomposed in the Tobit analysis. However, comprehensive external influencing factors can also be further divided in other manners, e.g., division of system factors and non-system factors, division of market factors and non-market factors. Other external influencing factors like differences in regional development strategy are also noteworthy. All of these factors are not considered in this paper, so they can be used for future in-depth researches.

结论

农村信息化发展效率评价对于提高农村信息化整体水平、优化农村信息化投入结构具有重要作用。本文运用 DEA 的 CCR 模型对 2007-2010 年间中国农村信息化发展效率进行了测度，研究发现，中部和东北地区的农村信息化发展效率低于东部和西部地区，Kruskal-Wallis 差异性检验显示，西部和中部，东部和中部发展效率都存在显著差异，“中部塌陷”现象在农村信息化发展表现明显；Tobit 分析表明，农村信息化建设发展项目是推动农村信息化整体发展效率提升的主要影响因素，区域经济发展水平、农村居民最终消费支出与农村信息化整体发展效率之间均呈现显著负相关性，人口年龄结构、文化程度结构与信息化整体发展效率之间存在相关性。

改善提高农村信息化发展效率的对策措施，首先仍然是继续加大全局性农村信息化基础设施建设，不同地区根据经济发展水平不同应实施地方性项目加以补充；中央政府主导的政策性农村信息化建设是在短期内取得巨大成就的主要原因，但农村信息化是一个复杂的社会化综合性工程，信息设施、信息服务等基础建设只是其中一部分内容，长期发展应建立在健全的农村信息化市场的基础上，因此要保证未来农村信息化的健康发展，应逐步从强调政策性供给转向同时重视发展市场消费需求、扩大农村信息化消费水平、优化消费结构。

本文的研究思路和方法对于深入进行农村信息化发展效率的相关研究具有一定的启示和借鉴意义。当然，本研究仍存在需要改进和讨论之处：DEA 分析阶段主要涉及模型变量指标的选取，在评价信息化水平中是否应该包括教育变量指标，信息产业宏观贡献变量指标等，有一定的争论；Tobit 分析阶段本文从消费环境和外部宏观发展环境角度选择了具代表性的影响因素指标，在模型分析中初步分解出全局性和地区性因素对农村信息化发展效率的影响，可以进一步考虑以其他方式细分外部综合性影响因素，如分为制度和非制度、市场和非市场因素，还可以考虑其他一些外部影响因素，如区域发展战略差异等，这些在本文中没有涉及，有继续深入研究的价值。

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