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Internet Development and Structural Transformation: Evidence from China

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Abstract

We study the effects of Internet development on structural transformation. To guide empirical work, we develop a basic model where the effect of Internet development on industrial development depends on the improvement of production technology of enterprises. We test the predictions of the model by studying the application of e-commerce, the sales revenue of basic software products and the number of computers used in China, which formed the basis of Internet development. We find that technical change and development in Internet was strongly labor-saving and led to industrial transformation, as predicted by the model.

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1. Introduction

The early development literature documented that a country's economic growth process is generally accompanied by a structural transformation process. As the economy developed, the employment ratio of the agricultural labor force gradually declined, and the agricultural labor force migrated to the city and transformed into the labor force in the manufacturing and service sectors (Clark, 1940; Lewis, 1954; Kuznets, 1957). The results of previous studies have shown that distinguishing and identifying the factors that lead to structural transformation is the key to understanding the process of economic development. A lot of literatures have studied the impact of technological development on industrial transformation, especially the impact of improved agricultural production technology on industrial change (Murphy, Shleifer and Vishny, 1989; Kongsamut, Rebelo and Xie, 2001; Gollin, Parente and Rogerson, 2002; Ngai and Pissarides, 2007; Baumol, 1967). At present, with the development of Internet and related technologies, the Internet is affecting manufacturers' production behaviors and consumer behaviors from the supply side and the demand side, and these effects will further affect the development and transformation of local industries. However, few scholars have studied the impact of Internet development on structural transformation.

In this paper, we show direct empirical evidence on the impact of Internet development on the three major industrial sectors by studying the scale of e-commerce transactions, the use of basic software products, and the scale of computers used in China in recent years. First, we analyze the impact of Internet-based e-commerce transactions. This new technology can produce the same yield with less labor, and it achieves an increase in general productivity. Second, we studied the impact of the scale of the use of basic software products. This technology provides the software foundation for the development and application of the Internet, effectively improving the automation level of enterprise production and reducing the use of labor. Third, we studied the impact of the scale of computers used. This equipment provides the hardware foundation for the development and application of the Internet, effectively improving the level of Internet infrastructure and reducing the investment in human resources in agriculture and manufacturing. The expansion of these three technologies allows us to assess the impact of Internet development on structural transformation in an open economy from different perspectives.

To guide empirical analysis, we establish a theoretical model describing a two-sector small open economy where the development and application of the Internet has had an impact on structural transformation. The model predicts that labor-augmenting technical change that result from the development of Internet applications will reduce the demand for agriculture and manufacturing labor and redistribute workers into the service sector. In summary, the model predicts that the impact of Internet development on structural transformation in an open economy depends on labor changes triggered by Internet applications. In the first analysis of the data, we found that in areas with larger e-commerce transactions, the number of workers in the service industry increased, the proportion of employment increased, and the output of each worker was reduced. At the same time, the employment ratio of the manufacturing sector in these regions will decline. These correlations are consistent with theoretical predictions that the applications of Internet-related technologies have reduced labor demand in the agricultural and manufacturing sectors and has led to the redistribution of workers into the service sector.

Furthermore, we obtained exogenous indicators reflecting changes in Internet development at the Chinese provincial level by using data from e-commerce transactions across different provinces in the Chinese National Bureau of Statistics database. The volume of e-commerce transactions reflects the application level of regional Internet technology from the perspective of consumers and enterprises. In addition, the database reports the number of computers used by each province at the end of each year, reflecting the level of development of Internet hardware. In the China Electronic Information Industry Statistical Yearbook, we further found the annual basic software product revenue data of each province, which reflects the development level of Internet software. Therefore, we use the differences in Internet technology indicators in different geographical regions of China as a source of cross-sectional changes in Internet development. In the model, we assume that goods can be circulated across different provinces, but labor cannot flow freely. Through this design, we can examine whether the external impact of local Internet development will lead to changes in the local industrial structure. We use the Chinese provinces as our sample units and assume that each province is a small open economy as described in the theoretical model.

We find that in areas with more advanced Internet development, the proportion of employment in the manufacturing sector has declined, the proportion of employment in the service sector has increased, and the number of employed workers in the service sector has increased. Interestingly, as the employment share of the service sector increases, the per capita output of the service sector may decline. This may be due to the rapid growth of the labor force in the service sector and the relatively slow increase in capital and output. Considering that Internet technology has affected the change of enterprises' generalized production technology, we refer to labor-augmenting technical change as labor-saving. Our regression estimates can be used to quantify the impact of local labor-saving Internet development on local structural transformation. In particular, we calculated how changes in Internet development characterized by e-commerce transactions affect the increase/decrease in the share of employment in the local industry sector: a 1 unit of increase in E-commerce transaction volume leads to a 0.0003 unit of increase in the service employment share and a 0.0003 unit of decrease in the manufacturing employment share. These quantitative estimates can be used to understand the extent to which the structural transformation of Chinese provinces can be explained by the labor-saving technology development of the Internet. We have verified the robustness of our benchmark estimates. First, when we take an indicator that reflects the use of regional software application as an Internet effect indicator, the estimate is stable. Secondly, when we take the indicators that reflect the level of construction of regional Internet hardware facilities as indicators of Internet effects, the estimates are also stable. We further introduce the analysis of the agricultural sector to complete our theoretical research framework.

In this paper we assume that labor is immobile across provinces, thus all the changes to labor-saving Internetization occurs through a reallocation of labor toward the services sector. However, if labors may relocate to other provinces, some of these changes would take place through out-migration. Due to China's stricter household registration system, some labor migration is a short-term behavior. On the other hand, there is a certain lack of statistics that fully describe these short- and medium-term labor migrations. Thus, a further investigation of the impact of internet development on migration flows is left for our future work.

The remaining of the paper is organized as follows. Section 1 gives background information and introduction. Section 2 provides literature review. Section 3 establishes the model. Section 4 describes the data. Section 5 presents the empirical results. Section 6 shows the robustness checks. Section 7 concludes.

2. Literature Review

There is a long tradition in studying the economic relationship between industrial development and structural transformation. Bustos, Caprettini and Ponticelli (2016) and Foster and Rosenzweig (2004, 2008) had studied the links between agricultural productivity and economic development. Our work refers to the theoretical model of Bustos, Caprettini and Ponticelli (2016) in analyzing the impact of increased agricultural productivity on manufacturing structure changes. Our treatment of services in the model refers to the three-sector open economy model with nontraded goods (Corden and Neary, 1982). This paper also refers to the literature on the role of manufacturing in economic development. Among them, some literature suggests that redistributing labor to manufacturing can increase aggregate productivity (Gollin, Parente and Rogerson, 2002; Lagakos and Waugh, 2013; Gollin, Lagakos and Waugh, 2014; Matsuyama, 1992). The development and application of the Internet is profoundly transforming the production and life of human society. Similar to the urbanization process, we are now in the process of Internetization of human society. Thus, we refer to the literatures focusing on the links between structural transformation and urbanization (Nunn and Qian, 2011; Michaels, Rauch and Redding, 2012).

In the study of the relationship between the Internet and economic structure, Shapiro and Varian (1998) argue that network effects can cause economies of scale and positive feedback on demand. Baccara et al. (2012), Angeletos and Pavan (2007) , Shy (2011) have studied issues such as externalities in the Internet economy. Jackson (2014) studied the impact of Internet-related attributes on people's economic behavior. Jorgenson, Ho and Stiroh (2008), Yushkova (2014), Ark, O'Mahony and Timmer (2008) discuss the impact of information technology represented by the Internet on productivity. Levin (2011) studied the relationship between the Internet and product sales. Mossel, Sly and Tamuz (2015) studied the behavior of network society and the efficiency of resource allocation from the perspective of game theory. Bramoulle, Kranton and Damours (2014) used game theory to study the relationship between network, resource allocation and market efficiency. In terms of the impact of the network on the market, Anderson (2006) pointed out that the Internet has realized the long tail demand and long tail supply. Choi (2010) found that Internet development can promote an increase in the export of service trade in a country. Similar studies are also found in Clarke (2008), Meijers (2014), Yushkova (2014), Vemuri and Siddiqi (2009).

There are a series of key documents on the relationship between the development of Internet intelligence technology and economic growth. Munshi (2014) and Czernich et al. (2011) proposed an economic growth theory based on the Internet. Choi (2010) and Czernich et al. (2011) discussed the relationship between the Internet and economic growth. Stevenson (2008) explores the relationship between the Internet and employment. Kuhn and Skuterud (2004) have shown that mastery of Internet skills can help expand employment. Anderson and Wincoop (2004) argue that the Internet can reduce international trade search costs and communication costs to promote trade development. Blum and Goldfarb (2006) found that even for network products, there are still search costs. Freund and Weinhold (2002) argue that Internet development can reduce the cost of entry to the enterprise and ultimately increase the overall size of international trade. Hellmanzik and Schmitz (2015) directly incorporated bilateral Internet development into bilateral trade costs and studied the impact of the Internet on exports.

3. Model

In this section, we illustrate the impact of Internet development on structural changes in open economies by constructing a theoretical model. This paper draws on the theoretical model of Bustos, Caprettini and Ponticelli (2016), and refers to the idea of technological development proposed by Neary (1981) and Acemoglu (2010). Based on the perspective of Internet intelligence technology affecting production technology, we construct a model of enterprise Internetization that affects industrial restructuring.

Early literature generally used Clark's law to measure the industrial structure upgrade based on the increase in non-agricultural output value. However, with the development of the information technology revolution, the trend of "prosperous development of the service industry" has gradually emerged in the economy, and the growth rate of the service industry is faster than that of the manufacturing industry. Therefore, some literatures use the proportion of service industry output as a measure to reflect the upgrading of industrial structure. In this model, we focus on the impact of the Internetization process on the proportion of labor in the three sectors of agriculture, manufacturing, and services, and examine whether Internetization drives labor to the service industry. From these aspects, we examine the upgrading trend of the industrial structure.

We first assume an area with the characteristics of a small open economy in which goods can trade freely across regions, but production factors are not mobile. In the context of an Internet-integrated market, we examine a provincial-level regional economic situation that has a free and open connection with the unified market. In this provincial area, there are two industrial sectors, "manufacturing and service", with two production factors "labor and capital". Suppose there are L residents in this regional economy, each resident represents one unit of labor; the manufacturing sector produces all kinds of goods, and the service sector produces various services. This paper assumes that the service sector only needs to invest in labor when it comes to service production. Its production function is $Q_s = A_s L_s$, where Q_s represents service industry output, L_s represents the number of labor in the service industry, and A_s reflects the technical efficiency of service production. It is assumed that the manufacturing sector requires both labor input and capital investment in the manufacture of commodities. It has the form of the Constant Elasticity of Substitution, which is expressed as follows:

$$Q_m = A_N \left[\gamma (A_L L_m)^{\frac{\sigma-1}{\sigma}} + (1-\gamma)(A_k K_m)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}} \tag{1}$$

In the above formula, Q_m represents the output of goods produced by the manufacturing sector. The two production factors invested are labor L_m and capital K_m, A_N is expressed as Hicks Neutral Technology Factor, A_L is a technical factor reflecting labor productivity efficiency, A_k is a technical factor that reflects the efficiency of capital production, $\sigma > 0$ is expressed as the elasticity of substitution between capital and labor, and $0 < \gamma < 1$. With the development and application of Internet intelligence technology (cloud computing, big data, artificial intelligence, Internet of things, virtual reality, etc.), the labor required by enterprises will show a downward trend. Especially for manufacturing sector, networked, automated, and intelligent production methods will further reduce the use of labor. This effect not only occurs in the narrow sense of production technology, but also in the financial management, marketing and supply chain management of the enterprise. Therefore, when we examine the manufacturing industry's Internetization, the most important impact of the application of Internet intelligence technology is to reduce the amount of labor used. This means that Internet technology is mainly reflected in A_L.

Based on equation (1), we can obtain the marginal output of labor in manufacturing:

$$MPL_m = \frac{\partial Q_m}{\partial L_m} = A_N A_L \gamma \left[\gamma + (1-\gamma)\left(\frac{A_k K_m}{A_L L_m}\right)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{1}{\sigma-1}} \tag{2}$$

It can be seen from the above formula that the increase of the Hicks Neutral Technology Factor A_N and the Capital Output Efficiency Technical Factor A_k will lead to an increase in the marginal output of the manufacturing labor force. For the technical factor A_L reflecting the labor productivity efficiency, there may be two opposite effects. On the one hand, the increase of A_L can increase $A_N A_L \gamma$; on the other hand, it can be known from $\frac{A_k K_m}{A_L L_m}$ that the increase of A_L will reduce the amount of capital provided by the unit labor. This effect is even greater when the replacement elasticity σ of labor and capital is small. The two factors are superimposed on each other, so that the total effect of the increase of A_L on MPL_m depends on the size of σ. Further analysis shows that when the substitution elasticity is at $\sigma < 1 - \beth \equiv \frac{K_m MPK_m}{Q_m}$, $\frac{\partial MPL_m}{\partial A_L} < 0$, the labor marginal output of the manufacturing industry decreases with the increase of A_L.

It is worth noting that since the manufacturing production function adopts the CES production function form, the output share of capital $1 - \beth$ is a function of the equilibrium employment level of the manufacturing industry. When $\sigma < 1$, the share of capital in the manufacturing industry increases as its employment level increases. Therefore, the condition $\sigma < 1 - \beth$ is more easily satisfied when the equilibrium employment level of the manufacturing industry is relatively high.

In the market equilibrium, according to the conditions of corporate profit maximization, we can know that the labor marginal output must equal the labor wage in the agricultural and manufacturing sectors: $P_m MPL_m = w = P_s MPL_s$. It can be further seen that in the market equilibrium, the marginal output of the labor force of the manufacturing industry is determined by the equilibrium service price of the service industry in the unified market and the technological productivity of the service industry, $MPL_m = (P_s/P_m)^* A_s$. These conditions, together with the market clearing condition "$K_m = K$" of the manufacturing capital, determines the distribution of the entire workforce in various sectors at equilibrium. Therefore,

$$L_m^* = \frac{A_k K_m}{A_L} \left(\frac{\gamma}{1-\gamma} \frac{1-\beth^*}{\beth^*} \right)^{\frac{\sigma}{1-\sigma}} \tag{3}$$

In the above formula, the output share of the entire labor force at equilibrium is: $\beth^* = \gamma^\sigma \left(\frac{P_s A_s}{P_m A_N A_L} \right)^{1-\sigma}$. On the other hand, the equilibrium employment level of the service industry L_s^* can be calculated by the labor market clearing condition "$L_m + L_s = L$". Once the equilibrium employment level L_m^* of the manufacturing industry and the equilibrium employment level L_s^* of the service industry are both determined, the output of each sector can be calculated by the respective production function.

Next, we examine how corporate Internetization affects structural transformation. As mentioned above, the most important impact of Internet intelligent technology is to reduce the use of labor when enterprises conduct Internetization. Therefore, among the three technical factors that affect the production function of the manufacturing industry, we mainly focus on the technical factor A_L of the labor-augmenting effect. The influence of A_L on manufacturing employment mainly depends on whether the substitution elasticity σ of labor and capital in the manufacturing industry satisfies $\sigma < 1 - \beth^*$. When this condition is met, we can say that capital and labor are strongly complementary. When capital and labor are strongly complementary, it can be obtained from equation (3):

$$\frac{\partial L_m^*}{\partial A_L} = \left(\frac{\gamma}{1-\gamma}\right)^{\frac{\sigma}{1-\sigma}} \left(\frac{1-\beth^*}{\beth^*}\right)^{\frac{\sigma}{1-\sigma}} \frac{A_k K_m}{A_L^2} \left(\frac{\sigma}{1-\beth^*} - 1\right) \quad (4)$$

It is known from the above equation that when $\frac{\sigma}{1-\beth^*} - 1 < 0$, $\frac{\partial L_m^*}{\partial A_L} < 0$. Based on $L_m^* + L_s^* = L$, we can derive $\frac{\partial L_s^*}{\partial A_L} > 0$. Therefore, the increase in A_L will affect the redistribution of labor between the industrial sectors and the changes in the output of the three sectors. Specifically, there are the following inferences:

1) An increase in A_L will increase the average labor output of the manufacturing sector $\frac{P_m^* Q_m^*}{L_m^*}$.

Proof: We can combine the formula (1) with the formula (2) to get the following formula:

$$\frac{Q_m}{L_m} = A_N A_L \left[\gamma + (1-\gamma)\left(\frac{A_k K_m}{A_L L_m}\right)^{\frac{\sigma-1}{\sigma}}\right]^{\frac{\sigma}{\sigma-1}} = \gamma^{-\sigma}(A_N A_L)^{1-\sigma}(MPL_m)^{\sigma}$$

Considering that P_m^* is determined by the equilibrium result of the unified market, it can be seen from the above equation that when $\sigma < 1$, the increase of A_L will increase the unit labor output during equilibrium.

2) The increase in $\mathrm{A_L}$ will reduce the relative capital intensity of manufacturing labor $\frac{\mathrm{L_m^*}}{\mathrm{K}}$.

Proof: Since $\frac{\partial L_m^*}{\partial A_L} < 0$, and the total amount of the endowment of K is fixed, then $\frac{\partial \frac{L_m^*}{K}}{\partial A_L} < 0$.

3) An increase in $\mathrm{A_L}$ will reduce the labor share of manufacturing $\frac{\mathrm{L_m^*}}{\mathrm{L}}$.

Proof: Since $\frac{\partial L_m^*}{\partial A_L} < 0$, and the total amount of L is fixed, then $\frac{\partial \frac{L_m^*}{L}}{\partial A_L} < 0$.

4) The increase in $\mathrm{A_L}$ will increase the labor employment share of the service industry $\frac{\mathrm{L_s^*}}{\mathrm{L}}$.

Proof: Since $\frac{\partial L_s^*}{\partial A_L} > 0$, and the total amount of L is fixed, then $\frac{\partial \frac{L_s^*}{L}}{\partial A_L} > 0$.

In summary, it can be seen that under the impact of the Internet and related intelligence technologies, with the deepening of the enterprise Internet process in the manufacturing industry, the alternative of the Internet intelligence system to the traditional labor force is enhanced. This has led to an increase in the labor output of the manufacturing sector and a reduction in the concentration of labor in the manufacturing industry relative to capital. More importantly, this further promotes the transfer of the labor force in the manufacturing industry to the service industry. In the above model, we only examine the situation in which only the manufacturing and service sectors exist, and analyze the structural transformation under this situation. In fact, under the logical framework of this model, if a two-sector model of agriculture and services is established, the agricultural production function can be set to $Q_{\mathrm{a}} = A_N\left[\delta(A_{La}L_a)^{\frac{\tau-1}{\tau}} + (1-\delta)(A_T T_a)^{\frac{\tau-1}{\tau}}\right]^{\frac{\tau}{\tau-1}}$, where Q_a represents the agricultural output of agriculture, and the two production factors invested are labor L_a and land T_a, A_N is expressed as Hicks Neutral Technology Factor, A_{La} represents technical factor reflecting labor efficiency, A_T represents technical factor reflecting land use efficiency, and $\tau > 0$ is expressed as substitute elasticity of capital and land. In this case, $0 < \delta < 1$. Then, we can get similar conclusions when it comes to the two sectors of the manufacturing and agriculture industries. That is to say, the development of the Internet has promoted the trend of prosperous development of the service industry.

In the impact of Internet intelligence technology on agriculture and manufacturing, the similarities between these two sectors is that Internet development has reduced the demand for labor. Further, when we consider establishing a theoretical model that includes three industrial sectors, the conclusions will be similar to the conclusions derived from the theoretical models of the manufacturing and service sectors. That is to say, the development of the Internet has promoted the trend of prosperous development of the service industry. In short, when we analyze the process of enterprise Internetization based on the perspective of changes in production technology, we see that the development of Internet intelligence technology has promoted the growth of service industry which is faster than manufacturing. Furthermore, the labor force in agriculture and manufacturing is shifting to the service industry. In the subsequent content of this paper, we test the theoretical results through empirical analysis.

4. Data

The main data sources are the database of National Bureau of Statistics of China. To perform robustness checks we also use the data related to the sales revenue of basic software products from the China Electronic Information Industry Statistical Yearbook. The National Bureau of Statistics of China publishes annual output values and employment-related data for agriculture, manufacturing, and services in each province. Based on these data, we can calculate and obtain relevant indicator data describing the transfer of industrial structure in each provincial level. The three variables that we are interested in reflecting structural transformation are the per capita output of labor, the number of labor, and the proportion of labor employment in agriculture, manufacturing, and service industries.

From the perspective of Internet application, the core explanatory variable selected in this paper is "e-commerce transaction amount". The reasons for the selection are as follows: First, the number of enterprises that conduct e-commerce directly reflects the extent to which enterprises use the Internet for electronic network transactions and business activities. Therefore, this is a reasonable indicator reflecting the degree of corporate Internetization. Second, the development of e-commerce is the primary foundation of any organization (enterprise, government, etc.) to carry out "internetization". Any content and work related to "internetization" of enterprises must first be considered based on e-commerce. Third, the data of e-commerce transactions in the provinces published by the National Bureau of Statistics of China during 2013-2017 reflects the level of Internet e-commerce use in this region. Therefore, it is a reasonable practice to use the e-commerce transaction volume to represent the level of enterprise Internetization in the region. For the sake of robustness, we have further sought other explanatory variables that can represent the Internet effect of enterprises, including: the sales revenue of basic software products in the region, and the number of computers used in the region at the end of each year. These two indicators further decompose the regional Internet development effects into two dimensions of software and hardware, thus examining the Internet development effects of the regions in different dimensions. One of the most important inputs for enterprises to carry out "Internetization" construction is the costs of Internet software developing, programming, and technical support. Therefore, the sales revenue of basic software products in the region can reflect the level of application of Internet-based software in regional enterprises, so it is a reasonable indicator for the level of regional Internet applications. With the advent of the Internet society, most computers will access the Internet. The number of computers used at the end of each year reflects the extent to which the region applies the Internet through the use of computer terminals. Therefore, the number of computers used in the region at the end of each year can reflect the development level of regional Internet hardware, so it is a reasonable indicator reflecting the regional Internetization effect. The summary statistics of main variables at provincial level is shown in Table 1.

Table 1: Summary Statistics of Main Variables at Provincial Level

	N	Mean	Min	Max	SD
Total employment					
Manufacturing	151	780.562	28.920	2,563.502	716.730
Service	151	995.250	83.800	2,439.850	619.569
Output per worker					
Manufacturing	151	15.865	8.227	36.601	6.003
Service	151	10.732	4.015	23.554	4.374
Employment share					
Manufacturing	151	0.258	0.118	0.500	0.095
Service	151	0.404	0.225	0.806	0.104
Internet development					
E-commerce transaction volume	155	23.885	0.194	185.480	33.512
log sales revenue of basic software	116	11.956	7.033	15.354	2.060
log number of computers used	155	4.376	0.540	6.653	1.166

5. Empirics

In this section, we will examine the impact of Internet development on China's structural transformation through empirical analysis. For this purpose, we first study the impact of e-commerce transaction volume on the productivity, employment and employment ratio of the service sector. Next, we will assess the impact of Internet technology development on the productivity, employment, and employment ratio of the manufacturing sector, and examine the distribution of labor across sectors.

We first explain the correlation between the increase in e-commerce transaction volume between 2013 and 2017 and the change in the employment ratio of the three industrial sectors. Based on the basic correlation analysis of these data, we try to answer the question: does the increase in the volume of e-commerce transactions in provincial regions promote (or delay) structural changes? First, we propose a set of panel data estimation equations that correlate various development indicators of the service industry with e-commerce transactions. Second, we relate manufacturing development indicators to e-commerce transactions. The basic form of the equation to be estimated in this section is:

$$y_{it} = \alpha_0 + \alpha_1 internet_{it} + u_i + z_t + \varepsilon_{it} \tag{5}$$

where i indexes the province, t indexes time, u_i are provincial fixed effects, z_t are time fixed effects, y_{it} is an outcome that varies across provinces and time, and

$internet_{it}$ is the variable indicating the internet development. To further remove the effects of time series trends, we estimate equation (5) in first differences:

$$\Delta y_{it} = \alpha_1 \Delta internet_{it} + \Delta z_t + \Delta \varepsilon_{it} \tag{6}$$

To accurately select the type of regression estimation model, we performed a rigorous panel data model selection test for each regression estimate. Therefore, a suitable model can be selected from the fixed effect model (FE), the random effect model (RE), the pooled OLS regression model (POLS), and the two-way fixed effect model (TWFE) of the panel data. The model selection tests used in this paper are: 1) An F test for checking that "all individual dummy variables are 0". 2) The Hausman test for testing "individual effects are not related to explanatory variables" is mainly used to select from random effects models and fixed effect models. 3) The LM test (B-P test) used to test the "existing individual effects" is mainly used to select from random effect models and pooled OLS regression models. 4) LR test for checking whether the time effect is significant. These test results are detailed in each regression table. In the following section of estimating the subsequent robustness test, the paper continues to give relevant model selection tests' results.
Service Outcomes: Total Employment, Productivity, and Employment Share.— Table 2 reports TWFE (Two-Way Fixed Effect) estimates of equation (6) for three service outcomes. The first is total employment in service sector. The second is labor productivity, measured as the value of output per worker in service. The third outcome is the employment share of service.

Table 2: Basic Correlations in the Data: Service
(Total Employment, Productivity, and Employment Share)

	Δ employment	Δ output per worker	Δ employment share
Model	TWFE	TWFE	TWFE
Δ e-commerce transaction volume	1.3218***	-0.0325***	0.0003***
	(3.4089)	(-3.8660)	(2.7972)
Constant	33.6477***	0.5470***	0.0098***
	(6.1700)	(4.6213)	(5.8473)
Observations	119	119	119
Number of id	31	31	31
R^2 Within	0.1854	0.2872	0.1349
F Test (P value)	2.6785	1.8744	1.9752
	0.0002	0.0128	0.0077
Hausman Test (P value)	0.0666	24.3181	1.6973
	0.7964	0.0000	0.1926
LM Test (P value)	15.5616	1.1334	6.2165
	0.0000	0.1435	0.0063
LR Test (P value)	10.0007	23.2641	9.3992
	0.0186	0.0000	0.0244
Notes: Significance levels: *** p<0.01, ** p<0.05, * p<0.1.			

The first two columns of Table 2 show that in areas where e-commerce transactions were expanded, the number of laborers in the service sector has increased and the share of employment has risen. The results of these empirical studies are consistent with our previous theoretical model derivation, that is, the development of the Internet has promoted the transfer of labor from other sectors to the service sector. The estimated coefficients imply that a 1 unit of increase in E-commerce transaction volume corresponds to a 1.3218 unit of increase in total employment, and a 0.0325 unit of reduction in labor productivity. The reason may be that the service sector has a lower contribution rate to capital in the output than the manufacturing sector, while the labor contribution ratio is higher. When the number of labor in the service sector increases, the rate of increase in labor is greater than the rate of increase in output in the service sector, which may lead to a decline in labor productivity. The third column of Table 2 suggests that Internet development has not only increased the number of labor in the service industry, but also expanded the share of labor employment. The estimated coefficients imply that a 1 unit of increase in E-commerce transaction volume corresponds to a 0.0003 unit of increase in employment share.

Manufacturing Outcomes: Total Employment, Productivity, and Employment Share.—Table 3 reports panel estimates of equation (6) for three manufacturing outcomes. The first is total employment in manufacturing sector. The second is labor productivity, measured as the value of output per worker in manufacturing sector. The third outcome is the employment share of manufacturing sector.

Table 3: Basic Correlations in the Data: Manufacturing
(Total Employment, Productivity, and Employment Share)

	Δ employment	Δ output per worker	Δ employment share
Model	TWFE	POLS	TWFE
Δ e-commerce transaction volume	0.1943	0.0196	-0.0003***
	(0.9371)	(1.3971)	(-2.8548)
Constant	5.4731*	0.4196***	-0.0003
	(1.8770)	(2.8731)	(-0.1936)
Observations	119	119	119
Number of id	31	31	31
R^2		0.0164	
R^2 Within	0.1251		0.1407
F Test (P value)	3.5930	0.7577	3.7366
	0.0000	0.8029	0.0000
Hausman Test (P value)	0.1456	1.1370	0.0235
	0.7027	0.2863	0.8782
LM Test (P value)	28.7061	0.0000	31.3334
	0.0000	1.0000	0.0000
LR Test (P value)	13.7055	5.5566	10.9045
	0.0033	0.1353	0.0123

Notes: Significance levels: *** p<0.01, ** p<0.05, * p<0.1.

The third columns of Table 3 show that in areas where e-commerce transactions were expanded, the share of labor employment in the manufacturing sector has decreased. The estimated coefficients imply that a 1 unit of increase in E-commerce transaction volume corresponds to a 0.0003 unit of decrease in employment share. These empirical results are consistent with the above theoretical analysis, that is, Internet development has promoted strong labor-savings in the manufacturing sector. In the region where e-commerce transactions are expanding, the decline in manufacturing employment share suggests that the adoption of Internet technology will reduce the labor demand of manufacturing.

6. Robustness Checks

This section selects different explanatory variables based on the two dimensions of "software-hardware" in the Internet development, and conducts a series of robustness tests. Based on Table 2 and Table 3, this section looks for other proxy variables beyond the e-commerce transaction volume for Internetization effects, including the sales revenue of basic software products and the number of computers used at the end of each year. Similar to the basic regression, we continue to use equation (6) for regression.

Internet applications are inextricably linked to software applications, and software is an important foundation for Internet services. The "Internetization" of enterprises in a region needs to be realized through the development of application software and procurement of technical services. Therefore, the more the sales revenue of software business in a region is, the higher the degree of enterprise Internetization in the region is. We examine the impact of regional basic software product revenues on manufacturing output.

Table 4 reports the panel regression estimates for the three manufacturing output indicators for regional basic software product revenues. The first is the number of labor, measured by the number of workers in the manufacturing sector. The second is labor productivity, measured by the output value of each worker in the manufacturing industry. The third is the share of employment in the manufacturing sector.

The first column of Table 4 shows that in the regions where the sales revenue of basic software products is high, the number of laborers in the manufacturing sector has declined. The second column of Table 4 shows that in areas where the sales revenue of basic software products is high, the productivity of the manufacturing sector's workforce increases. The third column of Table 4 shows that in the regions where the sales revenue of basic software products is high, the employment share of the manufacturing sector declines. This means that the productivity of each manufacturing worker increases and the employment share of the manufacturing sector declines. The results of these empirical studies are consistent with the theoretical characteristics of Internet development, which shows the labor-saving effect. The estimated coefficients imply that a 1 unit of increase in the sales revenue of basic software products corresponds to a 0.5774 unit of decrease in total employment, a 0.0314 unit of increase in labor productivity and a 0.0002 unit of decrease in employment share.

Table 4: The Effect of Internet Software on Manufacturing
(Total Employment, Productivity, and Employment Share)

	Δ employment	Δ output per worker	Δ employment share
Model	TWFE	POLS	POLS
Δ log sales revenue of basic software	-0.5774**	0.0314***	-0.0002**
	(-2.4001)	(2.9585)	(-2.1779)
Constant	31.2483***	0.7875***	0.0010
	(4.6698)	(7.0417)	(1.1247)
Observations	219	219	219
Number of id	29	29	29
R^2		0.0388	0.0214
R^2 Within	0.2077		
F Test	1.6936	0.9278	1.3609
(P value)	0.0214	0.5744	0.1181
Hausman Test (P value)	0.0094	0.2447	0.6802
	0.9228	0.6209	0.4095
LM Test (P value)	4.9512	0.0000	0.9301
	0.0130	1.0000	0.1674
LR Test (P value)	46.6236	60.6126	31.8073
	0.0000	0.0000	0.0000
Notes: Significance levels: *** p<0.01, ** p<0.05, * p<0.1.			

On the other hand, with the advent of the Internet society, most computers will access the Internet. The number of computers used in the region at the end of each year can reflect the extent to which people in the region use the Internet through computer hardware. We examine the impact of the number of computers used in the region at the end of each year on manufacturing results. Table 5 reports the panel regression estimates for the three manufacturing output indicators for the number of computers used at the end of the year. The first is the number of labor, measured by the number of workers in the manufacturing sector. The second is labor productivity, measured by the output value of each worker in the manufacturing industry. The third is the share of employment in the manufacturing sector.

Column 2 of Table 5 shows that labor productivity in the manufacturing sector is increasing in areas where computer use is high. Column 3 of Table 5 shows that the employment share of the manufacturing sector has declined in areas where computer use is high. This means that the productivity of each manufacturing worker increases and the employment share of the manufacturing sector declines. Similarly, the results of these empirical studies are consistent with the theoretical characteristics of Internet development. The estimated coefficients imply that a 1 unit of increase in the number of computers used corresponds to a 0.0621 unit of increase in labor productivity and a 0.0005 unit of decrease in employment share. These findings indicate that Internet hardware development has not only reduced the number of manufacturing labor, but also greatly saved labor resources. In this case, Internet development can increase labor demand in the service industry.

Table 5: The Effect of Internet Hardware on Manufacturing
(Total Employment, Productivity, and Employment Share)

	Δ employment	Δ output per worker	Δ employment share
Model	TWFE	POLS	TWFE
Δ log number of computers used	-0.3572	0.0621***	-0.0005**
	(-0.9109)	(2.6412)	(-2.5305)
Constant	11.1249**	0.0835	0.0040
	(2.0006)	(0.4046)	(1.4854)
Observations	119	119	119
Number of id	31	31	31
R^2		0.0563	
R^2 Within	0.1246		0.1241
F Test (P value)	3.2514	0.8267	3.6861
	0.0000	0.7169	0.0000
Hausman Test (P value)	5.2184	0.0532	43.6251
	0.0223	0.8177	0.0000
LM Test (P value)	22.3184	0.0000	23.9019
	0.0000	1.0000	0.0000
LR Test (P value)	12.6129	10.2032	14.5691
	0.0056	0.0169	0.0022

Notes: Significance levels: *** p<0.01, ** p<0.05, * p<0.1.

7. Final Remarks

This paper provides direct empirical evidence of the impact of Internet development on structural transformation. We identify these effects by studying the development of Internet applications in China in recent years. The development and application of Internet-related technologies has enabled manufacturing to reduce the number of workers and produce the same output, thereby increasing manufacturing labor productivity. The impact of Internet development on agriculture has a similar effect. The decline in manufacturing and agricultural labor has led to an increase in the labor force in the service sector and an increase in the share of employment. This has led to a new adjustment and distribution of the entire workforce among the three industry sectors. In this paper, we use the e-commerce transaction volume, the sales revenue of basic software products, and the number of computers used at the end of each year to estimate the causal impact of Internet technology application on the employment share of the three industry sectors. Our findings help to discuss the impact of Internet development on industrial upgrading in open economies. We believe that these effects are mainly determined by labor employment bias caused by Internet-related technological improvements.

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