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An Empirical Analysis on the Diffusion and Lagging Effects of Information Technology

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Abstract. *This paper studies the diffusional effect of information technology on the total productivity factor of the information sector and the non-information sector by employing panel VAR (vector auto regression) and the two-sector model from Feder. We found that information technology Granger-causes economic growth, and that it has a positive influence on the growth rates for the labor force and the overall economy. However, the influence ratio of information technology on capital output was not significant, and the lagging effects of information technology will emerge after two to five years. This paper utilizes the informatization development index via dynamic panel regression to study the influence factors that are affecting the lagging effects of informatization development. We discovered that the original value of infrastructure index, consumer applications index, phase-I lag, and phase-II lag indexes have a significant impact on the current information development index. The original values of industrial technology, intellectual support, and the development performance index in phase-I lag have a significant impact on informatization development index; however, the effects are dampened. We conclude that there is a need for further building of information platforms to promote and upgrade information consumption, while keeping a close eye on the diffusion of information technology, existing lagging effects, and strengthening the deep fusion of informatization and industrialization. Informatization does not reduce the employment rate but instead alters the employment structure.*
Keywords: Informatization, Industrialization, Knowledge Spillover, Diffusion Effect, Lagging Effect

1. **Introduction.** In the past, scholars deemed information technology capital as the condensation of informatization capital, which would have minor to no impact on economic developments. Solow [1] introduced the Productivity Paradox in 1987, also known prevalently as the Solow Paradox, holds that the effects of the computer age is seen everywhere but in productivity statistics. Savants accredited this phenomenon to statistical discrepancy and the lagging effects of information technology. The output values of the ICT (Information and Communication Technology)industry have resulted as spillover[2]. Information technology was adopted in a wide range of industries between mid to late 1990s, which brought on fast economic growth[3]. This growth exhibited both high accumulation of capital and a decline in total productivity factor, which could not be explained by neoclassical economic theories. Romer[4] suggested an endogenous economic growth model in 1986 that took into account of knowledge in the economic growth system, where he also provided illustration of knowledge spillover effect. Endogenous economic growth theory attributes the Solow Paradox to endogenization of technical progresses, such as

learning by doing, knowledge spillover, human capital accumulation, and the R&D of technology. Since endogenization of technology is the determinant factor for achieving sustained economic growth, it would also have an indirect impact on economic growth that is generated from existing technologies. Due to the externality of information technology or networks economy, this indirect impact is a sum of diffusional effects, lagging effects, and its chain reaction on economic growth[5]. Under the neoclassical economic growth theory, information technology is considered as production factors such as labor or capital. In this framework, information technology in the ICT industry is equivalent to capital input, which neglects the fact that, different from traditional economy, network economy possesses features such as increasing returns to scale, network externality, intensification of information technology capital, and information technology's diffusional and lagging effects. In the endogenous economic growth theory, information technology is brought into the economic growth model, while information network economy's externality is underlined[6]. Nevertheless, these studies regarding information network economy externality starts with technology externality, while the spillover of technology knowledge is not derived from market operation. We need to understand the impact that technology spillover and technology diffusion has on enterprise's production function itself and impact on co-related industries. At the present, there are many theories in regards to the enhancement that information technology has on economic growth, but there are few models and quantitative methods specially made for the accumulation and lagging effects of information technology. This paper aim to perform quantitative analysis for the diffusional and lagging effects of information technology by using panel data. The next section in this paper uses Feder's two-sector model to study and construct the path and transmission mechanism between informatization and sectors of national economy[7]. Section III utilizes panel variable to do quantitative analysis of the diffusional and lagging effect of informatization and economic growth developed by it. In section IV, through regression analysis of dynamic panel data, we study the dynamic lagging effects of informatization development factor.

2. **Model introduction.** This paper employs Feder's two-sector model to construct and study the path and transmission mechanism between informatization and various sectors of national economy. Feder's model was originally used to analyze growth and spillover from export sectors into non-export sectors, which was widely adopted in decomposition of influence that some specific industry or sector had on other industry or sector. Under the assumption that the entire national economy consists of two sectors, namely information sector and non-information sector, where Y,I, and N represent overall output of the national economy, output of information sector, and output of non-information sector. If we use output of information sector as the input factor for non-information sector, while at the same time, the output of information sector exerts an external effect on non-information sector, where we can calculate the contribution that information sector makes on the other sector by using the equation listed here:

$$Y = I + N \tag{1}$$

$$I = F(L_I, K_I) \tag{2}$$

$$N = G(L_N, K_N, I) \tag{3}$$

The total quantity of labor force and capital are shown as:

$$L = L_I + L_N \tag{4}$$

$$K = K_I + K_N \tag{5}$$

From equation (1), we get:

$$dY = dI + dN = F'_{L_I} dL_I + F'_{K_I} dK_I + G'_{L_N} dL_N + G'_{K_N} dK_N + G'_I dI, \quad (6)$$

where F'_{L_I}, F'_{K_I}, G'_{L_N}, G'_{K_N} and G'_I denotes labor marginal output, capital marginal output from information sector and labor marginal output, capital marginal output from non-information sector plus marginal output that brought on by information technology progress, respectively. To strike a balance between the two sectors' economy, we must equate marginal labor productivity with marginal capital productivity from these two sectors, which is expressed as:

$$\frac{F'_{L_I}}{F'_{K_I}} = \frac{G'_{L_N}}{G'_{K_N}}, \quad (7)$$

After the transformation, we get:

$$\frac{F'_{L_I}}{G'_{L_N}} = \frac{F'_{K_I}}{G'_{K_N}} = 1 + \eta, \quad (8)$$

The expression above explains the marginal productivity difference of capital input and labor force input between the two sectors. We combine formula 8 with formula 6 to get:

$$dY = G'_{L_N}(dL_I + dL_N) + G'_{K_N}(dK_I + dK_N) + \frac{\eta}{1+\eta}(F'_{L_I} dL_I + F'_{K_I} dK_I) + G'_I dI, \quad (9)$$

From formula 1 through 6, we can know that

$$F'_{L_I} dL_I + F'_{K_I} dK_I = dI, \quad (10)$$

$$dL_I + dL_N = dL, \quad (11)$$

$$dK_I + dK_N = dK, \quad (12)$$

By combining (10),(11),(12)with formula(9), we can obtain the following expression:

$$dY = G'_{L_N} dL + G'_{K_N} dK + (\frac{\eta}{1+\eta} + G'_I) dI, \quad (13)$$

Divide Y on both sides of the equation to get:

$$\frac{dY}{Y} = \frac{G'_{L_N}}{\frac{Y}{L}} \cdot \frac{dL}{L} + \frac{G'_{K_N}}{\frac{Y}{K}} \cdot \frac{dK}{K} + (\frac{\eta}{1+\eta} + G'_I)\frac{I}{Y} \cdot \frac{dI}{I}, \quad (14)$$

From the equation above, it is evident that information sector and non-information sector have different production functions, and the output of relevant input factors of these two sectors differ from each other. Suppose $\gamma = \frac{\eta}{1+\eta} + G'_I$, where γ represents the overall impact that information sector has on economic growth, among which $\frac{\eta}{1+\eta}$ is the productivity of the information sector, and G'_I is the spillover of the information sector. By simplifying expression (14), we get:

$$g(Y) = c + \alpha \cdot g(L) + \beta \cdot g(K) + \gamma \cdot \frac{I}{Y} \cdot g(I) + \mu, \quad (15)$$

As the formula derivation shown above, we conclude that the spillover of information sector is normally achieved through combined contribution from information knowledge and information technology. The spillover that information sector has on itself and non-information sector is produced from three methods, namely, increases of knowledge and capital output, total factor productivity raises generated by technology advances, and optimization of industry structure and resources allocation[8]. Since information knowledge and information technology has a lagging effect on non-information sector, by using panel

VAR, we attempt to analyze the diffusional and lagging effects of information knowledge and information technology in the next section.

3. **Analyzing diffusional effect via panel VAR.** One method to forecast economic variables such as *GDP* growth rate and unemployment rateis to forecast each variable by using uni-variate time series model, which ignores the interdependent mutual impact among variables. Another method, named Vector Auto Regression, is put forwarded by Sim(1980),where all variables are put in one system for forecasting. In this paper, the impact that information sector and non-information sector has on economic growth is an inter-connected system, we need to analyze it as a whole. Therefore, this paper, using (*GDP* growth rate),$\frac{K}{Y}$(capital output ratio), *RL*(labor force growth rate) and panel data of *IDI* (Information Development Index), discusses and analyzes the impact that information sector and non-information sector has on economy based on *PVAR*(Panel Vector Auto Regression). All data used in this paper are collected from New China 60 Years Statistics Compilation, China Statistical Yearbook, and *IDI*(Information Development Index). Empirical analysis is made through software Stata, version 13.0.

3.1. **Determining the lag order.** Firstly, with the assistance of *GMM*(generalized method of moments) of *PVAR*, we can determine the lag order. From table 1, it is obvious that *AIC*,*BIC*, and *HQIC* is at a minimum when the lag order is 3, where the *PVAR* model contains 36 parameters. When there are too many parameters involved, such as the one above, it is infeasible to interpret the economical meaning. Therefore, *PVAR* regression coefficient is not included in the empirical analysis, which mainly covers impulse response function, Granger casualty, and forecast variance decomposition.

Table 1. Determining the lag order

Lag order	AIC	BIC	HQIC
1	-4.82121	-3.63864	-4.35637
2	-4.60291	-3.21490	-4.05584
3	-5.02105	-3.40495	-4.38229
4	-4.57504	-2.70383	-3.83328

3.2. **Unit Root Test.** In light of deterministic trends of time series, structure alteration, or stochastic trend, which might not be stationary processes, we employed unit root test to examine its stationarity to avoid quasi-regression. According to the unit root test, all original values are non-stationary. However, the order of difference of these variables is shown in table 2, which rejected non-stationary hypothesis of the variables. The four variables do not have observably unit root, which can be regarded as stationary process. We set it as *I(1)*.

Table 2. Unit root test results

Variable	Z value of HT	P_Z	T value of ADF	P_T	Test result
dRGDP	-33.5985	0.0000***	-5.1757	0.0000***	stationary
dK/Y	-7.2798	0.0000***	-1.8912	0.0092***	stationary
dRL	-32.2788	0.0000***	-5.2252	0.0000***	stationary
dIDI	-29.2867	0.0000***	-4.4805	0.0000***	stationary

Note:*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$

3.3. **Granger Causality.** In economics, we need to confirm the causality, whether it is X to Y,Y to X, or a bilateral causality. The test method presented by Granger(1969) is listed as follows: If X Granger-cause Y and Y does not Granger-cause X, then the past value of X can be used for the prediction of future value of Y, but the past value of Y cannot be used to predict the future value of X. Since Granger causality test is only applied to stationary order or unit root processes with integrated relation, for unit root variables without integrated relation, we need to re-examine after we obtain stationary order through differentiation. Since first difference of these four variables is all first order integration *I(1)*, we obtain the Granger unit root test results shown in table 3 below. From table 3,we conclude that *GDP* growth rate for Granger-cause capital output ratio and informatization development index, which affects overall economic growth, Capital output ratio, and productivity Granger-cause informatization development index. The empirical analysis shows that informatization development index Granger-cause the *GDP* growth rate, labor force growth rate, and overall economic growth[9]. Which further explains that productivity from all sectors increases with the development of industrial informatization, which boosts economic growth. In fact, the information service industry takes in surplus labor force in large quantities. Therefore, with a decreasing unemployment rate, the economy slag. However, capital output does not only Granger-case economic growth. If we consider capital output as an industrial process and informatization development index as the informatization degree, a conclusion is made that there is still a long way to go for informatization development, which imposes a positive effect on capital productivity. In sum, these confirms our aforementioned hypothesis that information sector will lift productivity, be it in itself, non-information sector, or overall economic growth and of which generates a diffusional spillover effect.

Table 3. Grange causality test results

Causality(lagging 3)	Chi2	Degree of freedom	P Value	Test result
dRGDP→dK/Y	7.1384	3	0.068*	Exist causality
dRGDP→dRL	3.3078	3	0.347	Indistinct
dRGDP→dIDI	15.968	3	0.001***	Exist causality
dRGDP→ALL	40.841	9	0.000***	Exist causality
dK/Y→dRGDP	2.6455	3	0.450	Indistinct
dK/Y→dRL	2.6625	3	0.447	Indistinct
dK/Y→dIDI	8.6715	3	0.034**	Exist causality
dK/Y→ALL	17.393	9	0.043**	Exist causality
dRL→dRGDP	6.0283	3	0.110	Indistinct
dRL→dK/Y	5.2252	3	0.156	Indistinct
dRL→dIDI	8.8206	3	0.032**	Exist causality
dRL→ALL	13.44	9	0.144	Indistinct
dIDI→dRGDP	7.3468	3	0.062*	Exist causality
dIDI→dK/Y	1.7307	3	0.630	Indistinct
dIDI→dRL	10.967	3	0.012**	Exist causality
dIDI→ALL	31.845	9	0.000***	Exist causality

Note:*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$

3.4. **Impulse response function.** We can see the positive impulse effect that *GDP* growth rate imposes on informatization development index from figure 1.There is a fall back after the changes made by informatization development index reached a specific

TABLE 4. Impulse response function

	dRGDP	dK/Y	dRL	dIDI
dRGDP	positive	positive	negative then positive	positive
dK/Y	negative	positive then negative	positive then negative	negative
dRL	positive then negative	positive	positive then negative	positive
dIDI	positive then negative	fluctuate around zero	positive	positive

Note: the row variables represents Response function. The column variables represents Impulse function.

point, which explains rise and fall of *IDI* with the rise of *GDP* growth rate. While capital input imposes negative impact on *IDI*, although enormous at the beginning, the impact on *IDI* is lessening, which denotes that capital output will push and enhance the integration between informatization and traditional industry. Labor force growth rate has a positive impact on *IDI* and goes through the rise and fall processes as well. The *IDI* has a positive impact on *GDP* growth rate at first followed by a negative impact, which proves that there is a sustainable growth of information economy even with an economic slowdown[9]. As for the impact that *IDI* has on capital output fluctuates around zero, denoting a gap for integration of informatization and industrialization. Which supports the conclusion of Granger causality test that informatization does not Granger-cause capital output.*IDI* has a positive impact on labor force productivity that declines first followed by an increase, which refutes the concept that machines will replace and push out human labor, and that informatization will deteriorate unemployment rates. Besides, *IDI* will impose positive diminishing impact onto itself. These conclusions verifies that *IDI* Granger-cause the *GDP* growth rate, labor force productivity, and *IDI* itself. Table 4 is the cross table based on the effect of each variable impulse response according to the figure 1.

3.5. **Forecast variance decomposition.** We aim to calculate and measure the unique contribution of disturbance of all equations, hence, we adopted Cholesky's decomposition to measure the impact orthogonalization imposes on variables. Furthermore, the sum of contribution ratio of all variables has on forecast-error mean square difference equals to one. It is named *FEVD*(Forecast-error Variance Decomposition)[10].Based on these *FEVD* results, it is clear that with the increased of stages, the impact that *IDI* has on all variables is growing. From table 5, in stage one, the *IDI* barely has any impact on *GDP* growth,capital output, and labor force growth rate; While in stage two we start to see a pick up on impact; the impact becoming even more apparent after stage 3.These analyses are consistent with the research of Li Liwei(2013) who believed that the lagging effects of the internet takes effect in two to five years, peaking on the fifth year. From table 5, the impact of growth rate in stage 5 takes up 68.7 percent, informatization 17.4 percent, exceeding the capital output of 13.2 percent. Among the impact factors, capital output takes up the largest share at 44.5 percent,informatization 32 percent, surpassing *GDP* growth rate immensely (22.8%). For the long run, the integration between industrialization and informatization is highly beneficial to industrial upgrades and industrial transformation as well as economic development. With the increasing of stages, the impact ratio for *IDI* on *GDP* growth rate, capital output, and labor force growth rate increases5.7 percent, 2 percent, and 4.3 percent, respectively. Which explains further that informatization is indeed helpful for increasing all productivity factors, and generates spillover effect on both information sector and non-information sector. On the other hand, it indicates that the

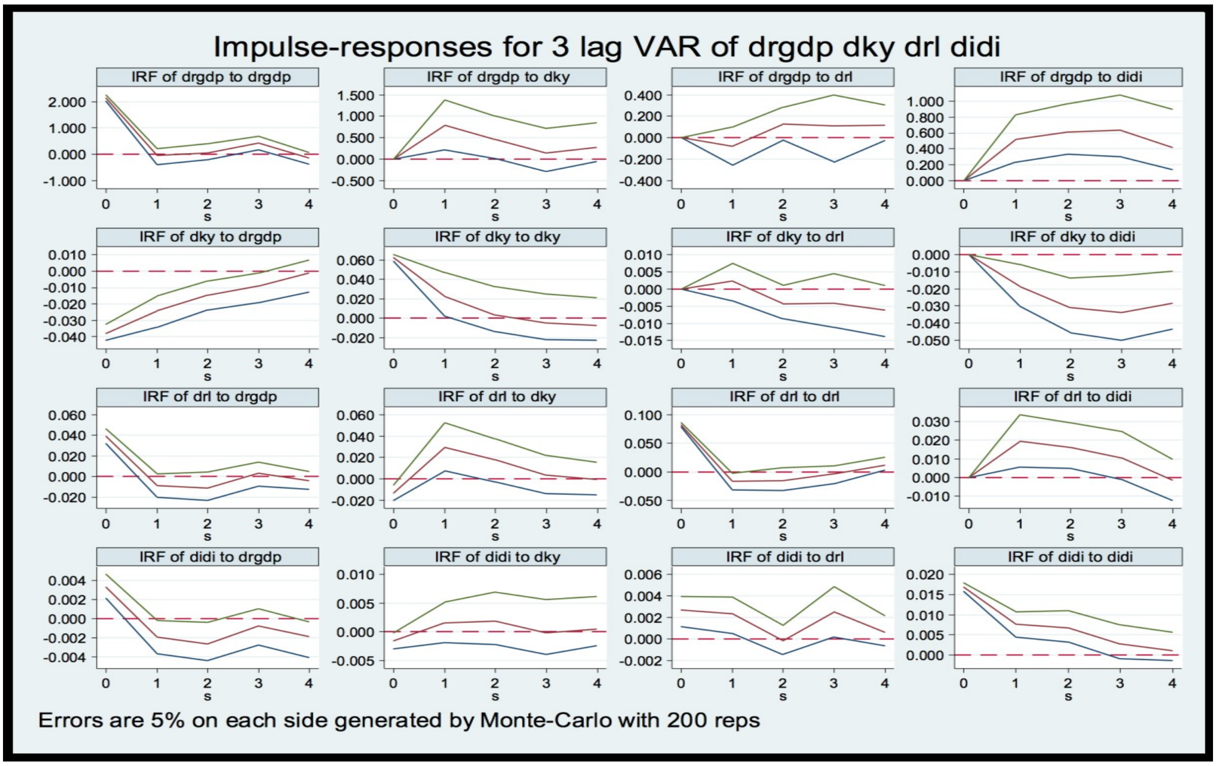

FIGURE 1. The impact figure of impulse response

TABLE 5. Forecast of the effects of variance decomposition

	Stage	dRGDP	dK/Y	dRL	dIDI
dRGDP	1	1.000	0.000	0.000	0.000
dK/Y	1	0.267	0.733	0.000	0.000
dRL	1	0.180	0.021	0.799	0.000
dIDI	1	0.035	0.009	0.024	0.933
dRGDP	2	0.836	0.113	0.001	0.049
dK/Y	2	0.297	0.651	0.001	0.051
dRL	2	0.159	0.105	0.698	0.037
dIDI	2	0.038	0.013	0.034	0.915
dRGDP	3	0.754	0.137	0.004	0.105
dK/Y	3	0.279	0.555	0.003	0.162
dRL	3	0.157	0.125	0.660	0.058
dIDI	3	0.050	0.020	0.029	0.901
dRGDP	4	0.712	0.127	0.005	0.156
dK/Y	4	0.250	0.482	0.004	0.264
dRL	4	0.156	0.124	0.652	0.068
dIDI	4	0.050	0.019	0.043	0.888
dRGDP	5	0.687	0.132	0.007	0.174
dK/Y	5	0.228	0.445	0.008	0.320
dRL	5	0.155	0.123	0.655	0.067
dIDI	5	0.057	0.020	0.043	0.880

Note: the row variables represents Impulse function. The column variables represents Response function.

degree of informatization is influenced by other product factors, and the industrialization will promote informatization convergence.

4. **Lagging effect analysis via GMM based on dynamic panel system.** Researchers hold the idea that an individual's current behavior depends on past behaviors because of inertia and partial adjustment, such as adjustments of capital stock. Considering that panel data consist of time series to dynamically monitor individuals, by inputting lagging values of explained variable into explanatory variable, we obtain dynamic panel data. The model is shown as:

$$y_{it} = \rho y_{i,t-1} + z + x_{it}^T \beta + \zeta_i^T \lambda + \alpha_i + \mu_{it}, \tag{16}$$

Even within groups, the estimation is inconsistent for panel data on investigating the influence factors and lagging effect of informatization in China. Therefore, we adopted regression system to perform regression tests by using dynamic panel data, which derives from 30 provinces and cities nationwide. We use *IDI* as explained variable y_{it}, *GDP* growth rate *RGDP*, capital output ratio $\frac{K}{Y}$, and the growth rate of labor force *RL* as control variable z. Using the perpetual inventory method, we regard the capital stock of information and communication industry (ITK),traffic of post and telecommunication (YWL) as endogenous variable(x_{it}). At the same time, we employ category index infrastructure (*infr*),technology(tech), application(*appl*), knowledge(*knowl*),and development performance(*perf*) as predetermined variable ζ_i^T. Since five categories of information index has measured China's informatization degree and performance in a comprehensive method, this paper aims to use dynamic panel system-GMM(System Generalized Method of Moments) to study and analyze the lagging effect that all influence factors of informatization have on China's informatization. All kinds of informatization index statistics is described in table 6.

Table 6. The description statistics of all kinds of informatization index

Variable	Quantity	Mean value	Standard error	Minimum	Maximum
perf	434	0.6202742	0.1313283	0.457	1.297
knowl	434	0.7912627	0.1096906	0.443	1.243
appl	434	0.5194562	0.1496997	0.316	0.976
tech	434	0.7824286	0.1787778	0.389	1.285
infr	434	0.345788	0.1558681	0.054	0.938

From the empirical results of table 7, which integrated test infrastructure index,technology index,consumer applications index,knowledge support index and development performance index of *IDI* effect of the regression results into table 7 , we can see that *IDI* is strongly influenced by phase-I lag and the influence coefficient surpasses 0.8863.Furthermore, because of the accumulation effect of informatization development, the influence coefficient of *IDI* is greater than 1 when performing the regress test between application index and development index. In the regression test between infrastructure index and application index, values that includes infrastructure index, application original value, index of phase-I lag, and index of phase-II lag all exert an enormous impact on the *IDI*, which means these indexes will continue to influence *IDI* in the long term. Another item to take into account is that the regression coefficient for infrastructure original value, phase-I lag, and phase-II lag(0.2043, -0.2724, 0.0935) is obviously greater than that of the applications' original value, phase-I lag, and phase-II lag(0.1344, -0.1161, -0.0343). In light of the crowding-out effect, the impact that infrastructure index has on *IDI* peaks at -0.2724 in

TABLE 7. Test different index of *IDI* effect of the regression results

Variable	Original value(T/P)	Phase-I lag(T/P)	Phase-II lag(T/P)
IDI		0.9888***/0.0261	
INFR	0.2043***/0.0146	-0.2724***/0.0196	0.0935***/0.0182
IDI		0.8863***/0.0079	
TECH	0.2581***/0.0142	-0.1628***/0.0070	0.0084/0.0086
IDI		1.0211***/0.0073	
APPL	0.1344***/0.0200	-0.1161***/0.0278	-0.0343***/0.0131
IDI		0.9357***/0.0126	
KNOWL	0.2015***/0.0157	-0.0903***/0.0311	-0.0292/0.0388
IDI		1.0027***/0.0110	
PERF	0.2059***/0.0269	-0.2191***/0.0197	0.0175/0.0109

Note:*$p < 0.1$, **$p < 0.05$, ***$p < 0.01$

phase-I lag and decline to 0.0935 at phase-II lag. While the application indexes original value during phase-I lag and phase-II lag are gradually declining, which suggests that there were informatization application demands at the start and those demands were not met. To fulfill those demands, drastic changes are needed to informatization. For instance, in the last century, the development of communication technology gave a big push for the rise of its derivative such as semi-conductor and electronic chips [11].Technology, knowledge, and performance index, be it original values, or phase-I lag and phase-II lag, all exerts huge impact on *IDI*, and the impact is gradually declining. Among these three indexes, the regression impact coefficient of technology is the largest at 0.2581.At the same time, the regression coefficient of knowledge and performance with its original value are respectively 0.2015 and 0.2059,the regression coefficient of knowledge at phase-I lag dives to -0.0903.Which means the contribution that labor force has on informatization is relatively small in the short term, to improve the spillover of information sector, the impact that knowledge makes on human capital and labor skills needs to be improved in the long term. From the regression results, we can conclude that there are lagging effects for all influence factors of *IDI*, the development of informatization cannot be accomplished overnight; it is not a sprint but a marathon. The improvements of information infrastructure, fulfilling user's various needs, industry innovation, and technology advancement are all progressive procedures.Meanwhile we can see that all informatization indexes, through radiation effect, are diffusing to other industries. To cite an example, infrastructure index and technology index comes into fruition in the telecommunication manufacturing industry and relevant supporting industries. Where application index and performance index, through consumption multiplier, boost consumption upgrade as to increase economic growth[12]. Based on the spillover of knowledge and learning by doing, the overall information and network awareness for Chinese citizen is on the rise, which will avoid economy divide intertwined with digital divide. It verifies the conclusion from section II that information sector has a spillover both on itself and non-information sector.

5. Conclusions.

5.1. **Building information platform and promoting information consumption advancements.** In section 4, where we perform the system-GMM regression between infrastructure index and application index, we find that the infrastructure index and application index with its original value and phase-I lag and phase-II lag will all have huge impacts on contemporaneous *IDI*. These two indexes represent the investment of information communication infrastructure and the consumption of information-based industry.

5.2. **Strengthen the leading edge of informatization and promoting deep integration between industrialization and informatization.** From the empirical analysis shown above, we can see that the regression coefficient of information infrastructure index and the original value of information technology index, which affects *IDI*, are 0.2043 and 0.2581.To add that their lagged value will affect *IDI* as well. By developing information technology, economic trends will head up.

5.3. **Valuing the diffusional and lagging effect of information technology's externalities.** In the Granger-cause test from section 3, there is a reciprocal causation between informatization development and economic growth. Based on the impulse-response function and forecast variance decomposition, we deduce that the lag stage that informatization imposes on economic growth is approximately two to five years. The impact is not shown as linear decrease as it should be abide by traditional economy's law of diminishing marginal return, but as a curved one even climbing up due to the accumulation effect.

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