Electronic Commerce, R&D, Externalities, and Productivity - An Empirical Study of Taiwanese Manufacturing Firms*

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Abstract

Using a newly constructed panel data on Electronic Commerce (e-commerce) and R&D investments by Taiwanese manufacturing firms during 1999-2000, this paper investigates the relationship between knowledge capital and productivity. The knowledge spillover consists of R&D spillover and e-commerce network externalities. Furthermore, this paper considers the impact of knowledge capital on capital productivity and labor productivity through substitution by applying a non-neutral production function. The empirical results show that: (1) both e-commerce and R&D capital have positive impact on productivity; (2) e-commerce stock and R&D capital tend to have a complementary relationship; (3) intra-industry e-commerce network externalities and inter-industry R&D spillover demonstrate a more significant contribution to productivity than the other two spillovers.

Keywords: Productivity, Taiwanese manufacturing firms, R&D spillover, e-commerce network externalities

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1. Introduction

As the global economic situation changes with each passing day, with the progression of information technology (IT), and under the application and diffusion of Internet and e-commerce, the global operational environment has varied greatly. For example, Dewan and Kraemer (2000) quoted a statistical survey by the International Data Corporation (IDC) in 1997, which showed that global IT expenditure increased from $162 billion in 1985 to $630 billion in 1996 and has a continuing rising trend. Starting from basically zero in 1995, total electronic commerce is estimated at some $26 billion for 1997 and predicted to reach $1 trillion in 2003-05 (OECD, 1999).

E-commerce growth to date has been quite impressive. For the sake of digesting information to create and accumulate knowledge as soon as possible, and for the purpose of consolidating their competence in competition and globalization, knowledge capital or technological capital has become the focal point and core factors of all industries. To reform products, exploit new products, or improve the process to decrease production costs, firms in Taiwan invest in reasonably large amounts of R&D expenditure.

Firms face continual and enormous investments in e-commerce and R&D, and they encounter higher risks. Firms also may have difficulties in repairing and operating these technical facilities, including excessive costs, lower cooperative willingness of up- and down-stream industries, and a lack of capability and related technological human resources. Consequently, no matter firms promote e-commerce and R&D investments with help by the government or firms accelerate their own e-commerce and R&D by themselves, it is worth exploring in depth the impact of e-commerce and R&D on productivity.

There are a large number of studies that have assessed the contribution of R&D to productivity at the firm level using panel data (e.g. Hall and Mairesse, 1995; Mairesse and Hall, 1996; Branstetter and Chen, 1999; Yang et al., 2001; Yang and Chen, 2002). Most of them show that knowledge capital and R&D expenditure do actually have a significant positive impact on productivity.

Despite the daily attention to the knowledge-based economy, many economists have claimed that e-commerce is a manifestation of the Internet and related technical progress, and e-commerce will dramatically reduce transaction costs and lead to a growth in productivity and economy through shifting the production frontier and/or increasing returns (Romer, 1986; Grossman and Helpman, 1991; Ajit, 1995; Aghion and Howitt, 1998 Lucking-Reiley and Spulber, 2001). However, there is surprisingly little empirical evidence on the impact of e-commerce on firms’ productivity.

With respect to research on e-commerce and productivity, Oliner and Sichel (2000) adopted “back of the envelope” calculations to explore the impact of e-commerce on
productivity in the U.S. during 1996-99, finding that e-commerce has no significant impact on MFP growth. Litan and Rivlin (2001) used “judgmental estimates” and showed the Internet’s contribution to productivity growth to be 0.2-0.4% per year over the last half of the 1990s. Goss (2001) examined the impact of actual Internet usage by industry for 1997-1999 by using pooled time-series and cross-section data, using job-related Internet usage as a proxy variable. Goss suggested that job-related Internet usage has a positive and statistically significant impact on productivity growth of roughly 0.25% per year. Konings and Roodhooft (2002) made use of a large representative data set of Belgium firms to study empirically the impact of e-business on productivity and cost efficiency of firms. They concluded that e-business had no effect on productivity in small firms, but selling online and e-procurement both had positive effect on productivity in large firms.

In these studies mentioned above, there is little empirical evidence on the impact of e-commerce on productivity, because e-commerce is a recent and rapidly evolving phenomenon and the measurement of e-commerce is difficult (Fraumeni, 2001). Since Internet usage prompts problems of measurement and quantification, and the application of electronic technology is comprehensive and not limited to Internet. In addition, Internet usage and dummy variables obviously cannot be ample enough to reflect the empirical dynamic situations of firms that engage in e-commerce investment. Therefore, this paper adopts an output-side indicator of e-commerce transaction as a proxy of e-commerce, which would be a proper and alternative way to measure the impact of e-commerce.

There are two types of network externalities, direct and indirect effect. The direct network effect comes from an increase in users, while the indirect effect comes from the development of applications (Katz and Shapiro, 1985; Mun and Nadiri, 2002). Therefore, another feature of e-commerce capital that distinguishes it from other traditional inputs is that it may generate considerable economic externalities. When the number of firms engaged in e-commerce and the items of electronic technologies adoption from firm $i$'s related industries are increasing, this could be helpful for firm $i$ to enhance productivity. Consequently, we place more emphasis on the network externalities of e-commerce in our empirical model.

In order to understand the impact on productivity of the rapid increase in e-commerce and R&D spending in recent years, this paper use a newly constructed panel data of Taiwanese manufacturing firms during 1999-2000. We investigate the relationship between knowledge capital (including both e-commerce and R&D investments) and productivity with the consideration of externalities. We also employ an output-side indicator of e-commerce transaction to construct e-commerce stock. Furthermore, this paper considers the impact of knowledge capital on capital
productivity and labor productivity through substitution by applying a non-neutral production function. The Generalized Method of Moments (GMM) approach is robust in the presence of heterocedasticity across firms and the correlation of disturbances within firms over time, and it is adopted to acquire more efficient estimators in this paper.

The rest of this paper is organized as follows. Sections 2 and 3 present the empirical models and data sources. In Section 4 we analyze the econometric results. Conclusions are in Section 5.

2. Empirical framework and measurement of spillover stocks

This paper assumes that the production function can be approximated by a Cobb-Douglas function:

\[ Y_{it} = A \epsilon^{\lambda t} \frac{CAP_{it}^{\alpha} LAB_{it}^{\beta} KNO_{it}^{\gamma}}{\epsilon^\omega}, \]  

where \( Y \) is value added, \( CAP \), \( LAB \), and \( KNO \) are the physical capital, labor input, and knowledge capital, respectively, and knowledge capital consists of firms’ own e-commerce stock (ECS) and R&D stock (RDS). The subscripts \( i \) and, \( t \) refer to the firm \( i \) and the current year \( t \), while \( \lambda \) is the rate of disembodied exogenous technical change and \( \epsilon \) is the error term reflecting the effect of unknown factors and other disturbances.\(^1\)

If the investment decisions on e-commerce and R&D are independent, then equation (1) can be written as:

\[ Y_{it} = A \epsilon^{\lambda t} \frac{CAP_{it}^{\alpha} LAB_{it}^{\beta} ECS_{it}^{\gamma} RDS_{it}^{\phi}}{\epsilon^\omega}. \]  

We can take logarithms to equation (2) and obtain the linear regression to implement the estimation of the Cobb-Douglas function as shown below:

\[ y_{it} = a + \lambda t + \alpha cap_{it} + \beta lab_{it} + \gamma ecs_{it} + \phi rd s_{it} + \epsilon_{it}, \]  

where the lower-case letter denotes the logarithms of variables, and \( \alpha \), \( \beta \), and especially \( \gamma \) and \( \phi \) (the elasticity of value added with respect to e-commerce and R&D) are the parameters of interest.

According to Kambil (1995) and Coble-Neal (2002), the behavior for firms to invest in e-commerce and R&D activities is not only for industrial transition and government policies, but also for the reason of relative technological application connections. Therefore, this paper releases the restriction of independence between e-commerce and R&D investments, and we allow this relationship to be a substitute

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\(^1\) The time trend \( \lambda t \) will be replaced with time dummies in estimation.
or a complement. Thus, the knowledge capital $KNO_{it}$ should be a function including the stock of accumulated past e-commerce and R&D investments.

Because e-commerce and R&D investments may generate considerable economic externalities, such as knowledge spillovers and network externalities, the exogenous variations of spillovers can influence the decision of firms’ and have an impact on productivity. When the effect of knowledge spillovers on firm $i$ from external sources is taken into account, it is partly determined by firms and serves as an endogenous variable (Adams, 2000). Therefore, we take account of spillovers of e-commerce and R&D into our model, and we can express $KNO_{it}$ as follows:

$$KNO_{it} = f(ECS_{it}, RDS_{it}, KS_{it}),$$  \hspace{1cm} (4)$$

where $KS_{it}$ is the stock of spillover.

This paper follows the work of Chen and Lu (2002) to construct two types of R&D spillover stocks - $Rstra$ and $Rster$. Term $Rstra$ represents the intra-industry R&D spillover, while $Rster$ represents the inter-industry R&D spillover by using the following definitions, respectively:

$$Rstra_i = \sum_{j \neq i}^N w_{ij} RDS_j,$$  \hspace{1cm} (5)$$

$$Rster_i = \sum_{j \neq i}^N w_{ij} RDS_j,$$  \hspace{1cm} (6)$$

where $w_{ij}$ is the ratio of firm $i$’s R&D expenditure to firm $i$’s 4-digit industry’s total R&D expenditure and $w_{ij}$ is the R&D expenditure of firm $i$’s 4-digit industry’s total R&D expenditure to firm $i$’s 2-digit industry’s total R&D expenditure.

In order to take into consideration the effect of e-commerce network externalities, we modify the of model Chen and Lu (2002) to construct two types of e-commerce network externalities stocks. Term $Estra$ represents the intra-industry e-commerce network externalities, while $Ester$ represents the inter-industry e-commerce network externalities by using the following definitions, respectively:

$$Estra_i = \sum_{i \neq j}^N n_{ij} ECS_j, \hspace{1cm} n_{ij} = de_{ij} + ie_{ij}$$  \hspace{1cm} (7)$$

$$Ester_i = \sum_{i \neq j}^N n_{ij} ECS_j, \hspace{1cm} n_{ij} = de_{ij} + ie_{ij}$$  \hspace{1cm} (8)$$

where $n_{ij}$ is the weight of intra-industry network externalities, and is composed of two effect: 1) direct effect $de_{ij}$ is the ratio of the number of firms engaging in e-commerce of firm $i$’s 4-digit industry to the total number of firms in firm $i$’s 4-digit industry. 2) indirect effect $ie_{ij}$ is the ratio of firm $i$’s electronic technology application index to firm $i$’s 4-digit industry’s total electronic technology application index. Term $n_{ij}$ is the weight of inter-industry network externalities and is composed
of two effect: 1) direct effect \( d_{i2} \) is the ratio of the number of firms engaging in e-commerce in firm \( i \)'s 4-digit industry to the number of firms engaging in e-commerce in firm \( i \)'s 2-digit industry. 2) indirect effect \( i_{i2} \) is the ratio of firm \( i \)'s 4-digit industry’s total electronic technology application index to firm \( i \)'s 2-digit industry’s total electronic technology application index.

Since each of these elements interacts with one another, these interactive effect and the specific functional form of \( KNO_{it} \) are unknown. Here we take the Tornquist input value index to construct the \( KNO_{it} \) index for our empirical model as follows:

\[
KNO_{it} = [(X_{1it})^{\phi_1} (X_{2it})^{\phi_2} (X_{3it})^{\phi_3} (X_{4it})^{\phi_4} (X_{5it})^{\phi_5} (X_{6it})^{\phi_6} (X_{7it})^{\phi_7}]
\]  

(9)

where \( X_1 \sim X_7 \) denotes ECS, RDS, ECS·RDS, Estra, Ester, Rstra, and Rster, respectively. \( \phi_i \) is the share of each variable of knowledge capital in the total value of the knowledge capital bundle.

Besides, intensive use of knowledge capital is likely to raise the capital (CAP) productivity and labor (LAB) productivity through substitution (Lucking-Reiley and Spulber, 2001). Therefore, the end result to production is a non-neutral shift of observed output; not only will productivity of inputs change, but also will the marginal rate of technical substitution (Huang and Liu, 1994). In this paper we apply a non-neutral production function different from the conventional model of equation (1). Our reformation of non-neutral production function is the following:

\[
Y_{it} = A e^{\lambda_1 t + \lambda_2 kno_{it} + \alpha_2 knocap_{it} + \beta_1 lab_{it} + \beta_2 kno_{it} lab_{it} + \varepsilon_{it}}
\]

(10)

Taking logarithms to equation (10) we obtain equation (11), which can be used to implement the relationship between knowledge capital and productivity.

\[
y_{it} = a + \lambda_1 t + \lambda_2 kno_{it} + \alpha_2 knocap_{it} + \beta_1 lab_{it} + \beta_2 kno_{it} lab_{it} + \varepsilon_{it}
\]

(11)

Equation (11) will be explored in this paper, and the general specification of equation (3) will also be discussed in our study for comparison.

In order to investigate the impact of related variables of knowledge capital on productivity, we use the estimated coefficients of equation (11) to calculate the partial average productivity (PAP) in the following way:

\[
PAP_i = \frac{y_{it}^{(2)} - y_{it}^{(1)}}{X_{i(t)} - X_{i(t-1)}}
\]

(12)

where \( y_{it}^{(1)} \) and \( y_{it}^{(2)} \) are the output contribution of variables \( i \) at time \( t-1 \) and \( t \) respectively while holding other variables constant, \( X_i \)'s are defined in equation (9).

3. Data sources and variable definitions
Owing to a lack of integrated data about e-commerce, R&D, and related firms’ operational information in Taiwan, this paper merges the automation and e-commerce survey and the plant survey of Taiwanese manufacturing firms during 1999-2000 provided by MOEA to obtain a more complete database. At the same time, taking into account the representation of industrial distribution and the length of time period, we construct a balanced panel data of 3,698 Taiwanese manufacturing firms for the survey period of 1999-2000.

In equation (2) of this paper, due to materials not included in the model, we use value-added ($VAL$), as the proxy variable of dependent variable $Y$. $VAL$ is equal to total output sales subtracting intermediate inputs. Total output sales have been deflated using a wholesale price index and intermediate inputs have been deflated using a price index of intermediate inputs. With respect to the explained variables of the right-hand side equation, physical capital ($CAP$) is total fixed capital and we use a capital price index to adjust for inflation, where labor ($LAB$) is the number of workers. This paper adopts an output-side indicator of e-commerce transaction as a proxy of e-commerce. Furthermore, e-commerce stock ($ECS$), R&D stock ($RDS$), and spillover stock ($KS$) are used to construct knowledge capital.

Our measurements of e-commerce and R&D stocks follow that of Mairesse and Hall (1996) and Yang and Chen (2002). They define the equation of knowledge capital stock as follows:

$$K_t = I_t + (1 - \delta)I_{t-1} + (1 - \delta)^2I_{t-2} + \cdots, \quad (13)$$

where $K$ represents the e-commerce and R&D stocks, $I$ is e-commerce transaction or R&D expenditure, and $\delta$ is the depreciation rate. Because of the limitation of the survey period, this paper adopts only one lagged year to construct knowledge capital stock. We assume that the above knowledge capital stocks have a constant depreciation rate of 15%, according to the general setting of previous papers.

As for the spillover effect, this paper considers the spillover effect of intra-industry and inter-industry. The total (e-commerce or R&D) spillover effect is the sum of intra-industry spillover effect ($Estra$ or $Rstra$) and inter-industry spillover effect ($Ester$ or $Rster$). We apply equations (5)-(8) to estimate intra-industry and inter-industry spillover effect. Table 1 gives sample statistics for our key variables.

4. Empirical results

In this section we present the results of the impact of e-commerce and R&D activities on productivity, which were achieved by applying GMM. The previous equation (2) is considered as the starting point of the analysis. We separate equation (2) into two estimative modes: mode (i) is a regression under the assumption that e-commerce
and R&D activities are independent (i.e. equation (3) of this paper); and mode (ii) is a regression that releases the restriction of e-commerce and R&D activities being independent, and it subsumes the e-commerce and R&D spillover effect of intra-industry and inter-industry under consideration, and we use those variables to construct the knowledge capital (i.e. equation (11) of this paper).

This paper tests the over-identifying restrictions by the Hansen J statistic, which is consistent in the heteroskedasticity presence. The test results of all modes do not reject the validity of instruments, as indicated by accepting the null hypothesis with a p-value above 0.05. The empirical results are presented in Table 2.

The second column of Table 2 shows the empirical results of mode (i), where the labor coefficient is higher than the capital coefficient, and they both have significant impact on productivity level. The first kind of knowledge capital, e-commerce stock \( \logECS \) and its parameter \( \gamma \) is positive significance at the 1% statistical level (the coefficient of e-commerce stock elasticity is 0.032). This provides evidence that Taiwanese firms devoting more e-commerce investment efforts have a better productivity performance, and this result is consistent with Konings and Roodhooft (2002), Litan and Rivlin (2001), and Goss (2001) in their findings.

We also explore another important knowledge capital, R&D stock, and detect the impact of R&D stock on productivity. The result shows that the coefficient of R&D stock \( \logRDS \) is 0.203, and the estimated R&D stock contribution to productivity is on the high end of Mairesse and Sassenou (1991) and Mairesse and Hall (1996). Their estimated R&D stock elasticity range of 0.008-0.210 in-developed countries. This magnitude is also higher than the average R&D elasticity of 0.036 for Taiwanese manufacturing firms in 1990-1997 as conducted by Yang and Chen (2002). This reveals that the contribution to productivity by investing in R&D activities by Taiwanese manufacturing firms is not inferior to those advanced countries. The above results have positive and constructive meanings to inspire Taiwan’s government to encourage and assist firms in investing and popularizing e-commerce and R&D activities.

The third column of Table 2 presents the estimates of the non-neutral production function of mode (ii). In order to investigate whether knowledge capital has influence on productivity, we use the \( F \)-test to test the joint null hypothesis about the parameters in this non-neutral production function model. The joint null hypothesis is \( H_0: \lambda_2 = \alpha_2 = \beta_2 = 0 \), and the alternative hypothesis is \( H_1: \lambda_2 \neq 0, \alpha_2 \neq 0, \) or \( \beta_2 \neq 0 \), or all are nonzero. Since \( F=16.55 \) and P-value <0.01, we reject \( H_0 \) and conclude that at least one of them is not zero, and thus knowledge capital has an effect upon productivity.

In the third column of Table 2, we find that all coefficients of parameters are
significance at the 5% statistical level. In order to investigate the impact of knowledge
capital on productivity of mode (ii) further, this paper estimates the partial average
productivity of each variable of knowledge capital. The results of the partial average
productivity estimates are shown in Table 3.

With respect to the empirical results of the relationship between e-commerce stock
and productivity, we find that partial average productivity of e-commerce stock is
small than the contribution of R&D stock toward output. The magnitude of partial
average productivity of e-commerce stock is approximately 0.045%, while the partial
average productivity of R&D stock is 0.272%. The gap between R&D contribution to
productivity and e-commerce contribution could be the reason why Taiwanese firms
did not widely adopted electronic technologies and the popularization of e-commerce
is not so common among all industries. In addition, many of the external benefits
from e-commerce, including automation of transaction, cost saving, added
convenience and reorganization of firms, that will gain productivity and are not
properly showed in the productivity statistics (Litan and Rivlin, 2001; Lucking-Reiley
and Spulber, 2001). Given the low usage rate of e-commerce activities, and the huge
amount of e-commerce transaction, there exists significant room for enhancing
productivity through a substantial expansion in e-commerce activities. Therefore, just
as Fraumeni (2001) mentions that although at this point e-commerce may represent a
relatively small percentage of both B2B and B2C, its future size and impact on
e-business process and economic growth may be large.

Moreover, the sign of partial average productivity for the interaction effect between
e-commerce and R&D stock is positive, implying that e-commerce and R&D
activities tend to have a complementary relationship in the production of knowledge
during the period of our study. We can infer that R&D and e-commerce activities
could integrate with each other to improve productivity, and this finding also
intensifies the credibility of our model’s setting.

As for the spillover effect, the intra-industry e-commerce network externalities
have played a more important role than the inter-industry e-commerce externalities in
terms of their impact on productivity. Its partial average productivity is 2.657% as
shown in Table 3. On the other hand, the inter-industry R&D spillover has a greater
contribution to productivity than the intra-industry R&D spillover. We also find that
e-commerce network externalities and R&D spillover have more significant impact on
productivity than e-commerce and R&D stocks. This connotes that some studies may
overestimate the impact of the knowledge capital of productivity when they neglect
the consideration of putting e-commerce and R&D spillover effect into their model.

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2 For example, the ratio of the number of firms that invest at least in one survey year in e-commerce to
the total number of observations is approximately 14.5% in our data set.
Our empirical finding verifies the claim of Carlsson (1997) that the most important features of technological systems are the characteristics of knowledge and spillover mechanisms.

5. Conclusion
Over the past decade, quite a few studies have adopted R&D as the proxy variable of knowledge capital in order to explore the relationship between knowledge capital and productivity. Nevertheless, knowledge capital is not restricted to R&D activities only; e-commerce activities also show a link to knowledge capital. For this reason, this study uses a newly constructed panel data on e-commerce and R&D investments of Taiwanese manufacturing firms during 1999-2000 to investigate the impact of R&D and e-commerce on productivity. The knowledge spillover consists of R&D spillover and e-commerce network externalities. Furthermore, this paper considers the impact of knowledge capital on capital productivity and labor productivity through substitution by applying a non-neutral production function.

The empirical results of this study indicate that: (1) both e-commerce and R&D capital have positive impact on productivity; (2) e-commerce stock and R&D capital tend to have a complementary relationship; (3) intra-industry e-commerce network externalities and inter-industry R&D spillover demonstrate a more significant contribution to productivity than the other two spillovers. This means that a firm’s productivity is not only affected by self-owned inputs, but also affected by the technological knowledge diffusion from up- and downstream firms or the same industry.

Finally, our empirical results would be a good reference for other developing countries. For further studies, the decomposition of e-commerce transaction into sales and procurement (i.e. e-sales or e-procurement), and the relationship between knowledge capital and spillover variables could be discussed in a detailed and accurate way in the future if a more detailed data were available.

References


Konings, J. and Roodhooft, F. “The Effect of E-Business on Corporate Performance:


### Table 1: Statistics on Variables (After Deflation), 1999-2000 (Million NT$)

<table>
<thead>
<tr>
<th>Variable</th>
<th>Name</th>
<th>Mean (S.E.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value added</td>
<td>VAL</td>
<td>418.026 (1864.660)</td>
</tr>
<tr>
<td>Capital stock</td>
<td>CAP</td>
<td>1,032.440 (6863.457)</td>
</tr>
<tr>
<td>Number of employees</td>
<td>LAB</td>
<td>177.186 (394.483)</td>
</tr>
<tr>
<td>E-commerce stock</td>
<td>ECS</td>
<td>132.274 (2450.291)</td>
</tr>
<tr>
<td>R&amp;D stock</td>
<td>RDS</td>
<td>29.398 (199.031)</td>
</tr>
<tr>
<td>Intra-industry e-commerce network externalities</td>
<td>Estra</td>
<td>713.670 (66.289)</td>
</tr>
<tr>
<td>Inter-industry E-commerce network externalities</td>
<td>Ester</td>
<td>2,689.660 (8280.890)</td>
</tr>
<tr>
<td>Intra-industry R&amp;D spillover</td>
<td>Rstra</td>
<td>20.858 (123.067)</td>
</tr>
<tr>
<td>Inter-industry R&amp;D spillover</td>
<td>Rster</td>
<td>288.356 (1022.265)</td>
</tr>
</tbody>
</table>

Note: The numbers in parentheses are standard errors.

### Table 2: Estimate of the Empirical Model (1999-2000)

<table>
<thead>
<tr>
<th></th>
<th>(i)</th>
<th>(ii)</th>
</tr>
</thead>
<tbody>
<tr>
<td>log ECS</td>
<td>0.0326 a (0.0125)</td>
<td></td>
</tr>
<tr>
<td>log RDS</td>
<td>0.2030 a (0.0264)</td>
<td>0.2881 a (0.0125)</td>
</tr>
<tr>
<td>log CAP</td>
<td>0.1271 a (0.0277)</td>
<td>0.8365 a (0.0200)</td>
</tr>
<tr>
<td>log LAB</td>
<td>0.7090 a (0.0573)</td>
<td></td>
</tr>
<tr>
<td>logKNO log CAP</td>
<td></td>
<td>-0.0010 b (0.0023)</td>
</tr>
<tr>
<td>logKNO log LAB</td>
<td></td>
<td>-0.0058 b (0.0036)</td>
</tr>
<tr>
<td>constant</td>
<td>-3.3563 a (0.8860)</td>
<td>0.0318 a (0.0100)</td>
</tr>
<tr>
<td>t</td>
<td></td>
<td>0.0318 a (0.0100)</td>
</tr>
<tr>
<td>$R^2$</td>
<td>0.882</td>
<td>0.855</td>
</tr>
</tbody>
</table>

Note: 1. The numbers in parentheses are standard errors. 2. a, b, and c represent the 1%, 5%, and 10% significant levels, respectively.

### Table 3: Partial Average Productivity of knowledge capital

<table>
<thead>
<tr>
<th></th>
<th>Partial Average Productivity (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ECS</td>
<td>0.045</td>
</tr>
<tr>
<td>RDS</td>
<td>0.272</td>
</tr>
<tr>
<td>ECS $\cdot$ RDS</td>
<td>0.181</td>
</tr>
<tr>
<td>Estra</td>
<td>2.657</td>
</tr>
<tr>
<td>Ester</td>
<td>1.362</td>
</tr>
<tr>
<td>Rstra</td>
<td>0.174</td>
</tr>
<tr>
<td>Rster</td>
<td>1.379</td>
</tr>
</tbody>
</table>