Studying complementarities between capital inputs in IT productivity analysis

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1. Abstract

- We study the differential effects of the various components of IT capital such as IT hardware, IT software and communications as well as non-IT capital; their interactions and the effects over time.
- The primary motivation for the study is the shift towards what has come to be referred to as "**IT enable economy**" in which value addition is linked to combining IT and ordinary capitals.

2. Introduction

- The studying impact of IT productivity extended many critical research areas for economists and IS scholars over the past decade.
- In 1995, Paul Romer [1] proposed the new computing metaphor of IT in production economic as oppose to the neoclassic classification of input capitals in productivity analysis. IT in production as a single input can be reclassified into three classes of inputs: (1) hardware (2) software and (3) wetware.

  Hardware: equipments, computers, raw materials and infrastructure

  Software: knowledge that has been codified and can be transmitted

  Wetware: human capital

- We apply the new computing driver perceptive into our analysis of IT productivity impact.

3. Approach

Production Function

We consider production function as the form

U= f(HC, SC, EC, OC ,L ; i, t)

Where ***output*** is U as value added and ***inputs*** are HC as IT Hardware capital, SC as IT Software capital, EC as Communication capital, OC as Ordinary capital and L as labor cost; the level of output will measure through industry sector type (i) for the specific year (t).

Interaction of different capital inputs in IT productivity analysis

- The most common functional form used in prior IT production Cobb-Douglas form is not suitable for our analysis since it restricts the rates of substitution between inputs to be constant. [2]
- A common form that allows variable rates of substitution as well as some other useful economic effects is the transcendental logarithmic, or "translog", function form. [3]
- With five inputs, the approach model would be estimated as

$$LnU_{it}=\beta_0+\beta_1 lnSC_{it}+\beta_2 lnHC_{it}+\beta_3 lnEC_{it}+\beta_4 lnOC_{it}+\beta_5 lnL_{it}$$
$$+\beta_6(lnSC_{it}*lnHC_{it})+\beta_7(lnSC_{it}*lnEC_{it})+\beta_8(lnSC_{it*}lnOC_{it})$$
$$+\beta_9(lnSC_{it*}lnL_{it})+\beta_{10}(lnHC_{it}*lnEC_{it})+\beta_{11}(lnHC_{it*}lnOC_{it})$$
$$+\beta_{12}(lnHC_{it}*lnL_{it})+\beta_{13}(lnEC_{it*}lnOC_{it})+\beta_{14}(lnEC_{it*}lnL_{it})$$
$$\beta_{15}(lnOC_{it*}lnL_{it})+$$
$$\beta_{16}(lnSC_{it})^2+\beta_{17}(lnHC_{it})^2+\beta_{18}(lnEC_{it})^2+\beta_{19}(lnOC_{it})^2+\beta_{20}(lnL_{it})^2$$
$$+\theta_i I+\theta_t T+\varepsilon it$$

- We rely on the "translog" form because it does not require non-linear estimation techniques and appears to have better performance in terms of capturing variation in the substitution elasticities than other possible functional forms.

AES or Allen elasticity of substitution

- It is used to measure the degree of complementarity and substitutability.[4] Given production function with five inputs, AES for any two inputs is represented by

$$AES\delta sc*hc=\frac{SCfsc+HCfhc+OCfoc+Lfl}{SC*HC}*\frac{Fschc}{F}$$

Which fi = x=ϑU/ϑi means that partial derivation of value added (U) with respect to input i. Fschc is cofactor associated with schc. F is the bordered Hessian matrix (5*5) determinant as below:

$$\begin{vmatrix} 0 & f_{sc} & f_{hc} & f_{ec} & f_{oc} & f_l \\ f_{sc} & f_{sc}^2 & f_{schc} & f_{scec} & f_{scoc} & f_{scl} \\ f_{hc} & f_{hcsc} & f_{hc}^2 & f_{hcec} & f_{hcoc} & f_{hcl} \\ f_{ec} & f_{ecsc} & f_{echc} & f_{ec}^2 & f_{ecoc} & f_{ecl} \\ f_{oc} & f_{ocsc} & f_{ochc} & f_{ocec} & f_{oc}^2 & f_{ocl} \\ f_l & f_{lsc} & f_{lhc} & f_{lec} & f_{loc} & f_l^2 \end{vmatrix}$$

- If the AES is negative numbers, it indicates that two factors are complements. If AES is positive, then two goods are substitutes. If AES is zero, the prices of the two factors have no influence on their ratio (they are neither complements nor substitutes). [4]

4. Data

- We assembled annual panel data set from the publicly available National Accounts Division of the Australian Bureau of Statistics (ABS). The panel data set covers the period over 20 years (1990-2009) for 16 industries which covered both public and private sectors.

5. Findings

Table 1: Interaction of capital categories

	Mean	Std Error	Interaction
AES_{sc*hc}	-2.077***	0.286	Complementary
AES_{sc*ec}	-0.737***	0.043	Complementary
AES_{sc*l}	0.513***	0.024	Substitutable
AES_{sc*oc}	0.208***	0.010	Substitutable
AES_{hc*ec}	-0.398***	0.047	Complementary
AES_{hc*oc}	5.659***	0.498	Substitutable
AES_{hc*l}	14.744***	1.380	Substitutable
AES_{ec*oc}	-0.660***	0.058	Complementary
AES_{ec*l}	-0.390***	0.025	Complementary
AES_{oc*l}	-0.981***	0.053	Complementary

*** statistical significant at 0.001 level

- The table shows ten interaction pair-wise are significant at 1% level; there are **six complementary interaction pairs** and **four substitute interaction pairs** as below tables.

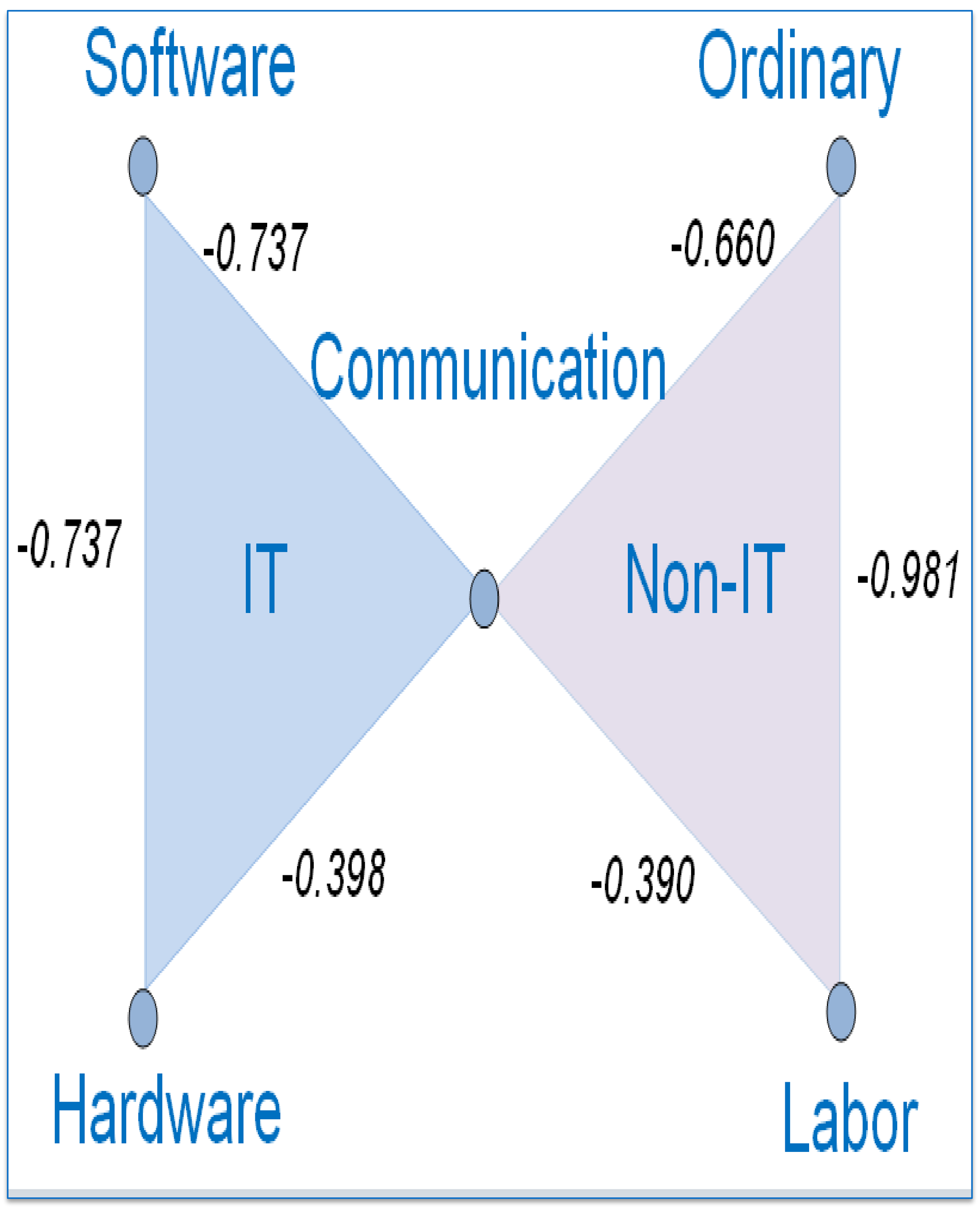
Four Substitute Interaction Pairs
Software & Ordinary capital
Software & Labor capital
Hardware & Ordinary capital
Hardware & Labor capital

- Software and Hardware capital are clearly substitutable to Ordinary capital and labor.

Six Complementary Interaction Pairs
Software & Hardware capital
Software & Communication capital
Hardware & Communication capital
Communication & Ordinary capital
Communication & Labor capital
Ordinary & Labor capital

- We have found that IT hardware and IT software are highly complementary in production (strongest amongst the six pairs) and IT hardware, when compare with IT software, is highly substitutable to the ordinary capital and Labour in production.

Figure 1: Complementary network Diagram of IT capitals and other



- We found two complementary clusters: (i) one can be labelled as IT-based cluster that consisted of IT hardware, IT software and communication inputs. (ii) The other can be labelled as ordinary-based cluster that consisted of ordinary capital, labour and communication inputs.

6. Conclusion

- Our above results showed that the 3 classes of IT capital inputs are highly complementary (not substitutable) which do not following the assumptions in neoclassical theory of economics in production. Furthermore, the IT communication seems to be the "KEY" complement of the two complementary clusters.
- Our results are consistent with Romer's new computing metaphor by which the definitions of capital inputs in productivity analysis would require much deeper consideration in the modern IT intensive economy.

7. References

[1] P. Romer, "Beyond the Knowledge Worker," in Wordlink 1995, pp. 56-60.
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[3] Christensen, L. R., D. W. Jorgenson, L. J. Lau. "Transcendental Logarithmic Production Frontiers. The Review of Economics and Statistics", 1973 vol. 55 pp. 28-45.
[4]S.Dewan & C.Min, "The substitution of information technology for other factors of production: A Firm's level Analysis",in Vol. 43, No. 12, pp. 1660-1675 Frontier Research on Information Systems and Economics (Dec., 1997).