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IT, Enterprise Reform and Productivity in Chinese Manufacturing Firms

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IT, Enterprise Reform and Productivity in Chinese Manufacturing Firms[1]

by Kazuyuki Motohashi[2]

Abstract

This paper is a first attempt of looking into the impact of IT and enterprise reform on productivity of Chinese manufacturing firms by using large scale firm level datasets from 1995 to 2002. It is found that enterprise reforms captured by entry and exit of firms have a positive impact on aggregated productivity growth. In addition, IT plays relatively more important role in productivity performance of post reform enterprises, as compared to enterprises which are not affected by major restructuring in the course of Chinese state owned enterprise reforms.

Keywords: Chinese firms, SOE reforms, Information technology, productivity

JEL classification: D24; D30; O57

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1. Introduction

Rapid technological progress of IT system and its diffusion into economy have played more and more important role in economic growth in developed countries. New economy, productivity lead economic growth in the Information Age can be found, not only in the United States, but also in Japan and Europe (Jorgenson and Motohashi, 2003, OECD, 2003). However, economic impact of IT in developing countries has not been investigated very much, although 'digital divide' is one of major policy issues. This paper provides empirical evidences on the relationship between IT investment and productivity for Chinese manufacturing firms from 1995 to 2002.

China shows outstanding economic performance since its economic reform started in 1980's. In these 20 years of Chinese economic development, we can observe a significant change of industrial structure from agriculture to manufacturing and service sectors. Within manufacturing sector, a shift of output from State Owned Enterprises (SOEs) to shareholding companies and foreign owned enterprises can be seen (NBS, 2004). In this process, a significant firm level dynamics can be observed by means of entry and exit of enterprise and its ownership change.

A whole process of enterprise reform by the Chinese government is targeted at revitalizing its economy by introducing market based competition. We cannot ignore this factor in analyzing the relationship between IT and firm's performance in China. In order to realize economic gains from IT investment, a firm must have a good incentive to improve its operational efficiency and to introduce new business processes or models which can be applied by using IT. Therefore, it is important to investigate the impact of economic reform as a necessary condition that Chinese firms can gain superior performance by IT investments.

This paper is a first attempt to analyze the impact of enterprise reform and IT on firm level productivity by using micro datasets by Chinese National Bureau of Statistics. Our dataset is covering about 25,000 manufacturing firms from 1995 to 2002, taken from NBS's Industry Statistics as well as Science and Technology Statistics. In this dataset, variables on inputs and outputs of conventional production function as well as IT related capital stock are available. In addition, since this panel data is based on census survey for all Large and Medium Enterprises (LMEs), the information on entry and exit from this dataset can be used as structural change variables for our empirical models.

This paper is organized as follows. In the next section, a brief history of economic

reform in China, including SOE reform and opening market policy for stimulating FDI, is presented. In addition, description of data as well as a quick overview of structural change of Chinese manufacturing industry, focusing on firm ownership change is provided. A section for productivity analysis, interacting enterprise reforms and IT capital intensity is followed. There are a number of past studies investigating the relationship between SOE reform and productivity, and a literature survey is also provided in this section. Then, a section for regression analysis for IT and productivity, and the impact of economic reform on this relationship follows. Finally, this paper is concluded with policy implications and future research agenda.

2. Economic system reform and its impacts on productivity

Many policies during economics reform that start in the end 1970s in China give more or less influence on ownership structure of enterprises. Early reform policy implemented in rural area created large number of enterprises run at town and village level, which latter are called as town and village enterprises (TVEs). Furthermore, open policy, which has been mainly characterized by more free trade and introduction of foreign investments, lead to emergence of businesses run by Taiwan, Hong Kong and Macao-based enterprises and foreign companies in Chinese market. Before the early 1990s foreign debts had consisted of inflow of foreign capital, but it was only from then the FDI took the place of foreign debts and formed main foreign investment. During his southern visit in 1992, Deng Xiaoping called for speeded up the economic reform and economic growth and brought about a boom of inflow of FDI. With strong competition of local government in attracting of foreign capital through such policy measures as favor taxes and provision land with low price for production use, the FDI achieved remarkable expansion, rising 4.4 billion US dollars (amount of the actually used) in 1991 to 11.0 billion of US dollars in 1992. It keeps up increasing from then, with only exception for two years of 1999 and 2000 due to Asian monetary crisis, and reached 53.5 billion of US dollars in 2003. The growing inflow of FDI into China has increase the importance of foreign enterprises in economy, which we will observe blow in the case of large and medium size enterprises.

Emergence and gradual grow of private enterprise and individual businesses (often referred to as getihu) have generated a new ownership component of Chinese enterprises since the beginning of economic reform. While the ordinance from the Chinese government was issued to protect the private enterprises and getihu, and at the same time to normalize their management behavior in the market, state protection was

granted to private enterprises for the first time by constitutional amendment in 1999. This is result of rapid expansion of private enterprise in China since it came out and will certainly its further development in the future.

Main policy measure that was taken to state-owned enterprises (SOEs) before 1994 is to improve their poor performance by giving them more autonomy, but almost without touching in their status of being state-owned.[3] In 1994 the Company Law was established for the first time in China. And one of its consequences is start and gradually acceleration of transition of SOEs to shareholding enterprises, for which the state holds the largest share in most cases. The reform of state-owned enterprises is accelerated in 1997. In this year, Premier Zhu Rongji announced in the 15th Party Congress his three years of schedule for accelerating SOEs' reform, which consists of measures such as implementation of "modern enterprise system", allowance of more SOEs to go to bankrupt, more redundancy of employment in SOEs and so on. Such strict measures have resulted in big decline in the number of SOEs and employment working for the SOEs.

In the process of SOE reforms, many of them were transformed to limited liability joint stock ownerships. The shares of this organization can be owned by the government as well as individual and institutional investors. However, in most cases, the government holds major share of new firms, so that this process is not fully privatization, but is called 'corporatization' under state control (Zhu, 1999). It has widely been, Qu (2003) for instance, argued that corporate governance change little in most of shareholding enterprises that are transited from SOEs, as government still take tight control of shareholding enterprises. There are also case studies shown how governmental intervention gives negative impact on shareholding enterprise (for example Watanabe, 2002). However, these series of enterprise reforms must have significant impact on incentive structures inside firms for improving productivity, as compared to an era of centrally planning system.

Given previous dominance of SOEs in Chinese economy and important consequences of reforming the SOEs to many aspects of the economy, it is not surprised that there have been a large body of literature devoted on enterprise reform in China Most of previous study have focused on efficiency consequences of enterprise reform for the SOEs. Jefferson et. al (2000) for instance, investigates productivity outcomes for three

[3] For detail about enterprise reform before beginning of 1990s, refer to Jefferson and Rawski (1994).

types of enterprises: state-owned enterprises (SOEs), collective-owned enterprises (COEs) and other ownership enterprises (OTEs) from 1980 to 1996. They find that productivity growth in OTEs is modest as compared to SOEs and COEs, and productivity of stock ownership enterprises was actually declined in 1990's. Zhang et. al (2001) analyze impact of ownership on productivity, and find that efficiency score of foreign owned enterprises is the highest, and that of state owned enterprises is the lowest.

There are some studies focusing on state-owned enterprises to analyze productivity performance. Zheng et. al (2003) uses the data of 600 SOEs from 1980 to 1994, and evaluate their efficiency level by using data envelopment analysis (DEA) and Malmquist index. The study find that, (1) the best practice SOEs are most likely to be found among large enterprises located in the well-developed coastal provinces, (2) wage incentives and capacity utilization had positive impacts on productivity growth, and (3) education had a significant effect on technical efficiency. Movshuk (2004) provides a case study of iron and steel industry, which have gone through substantial restructuring of SOEs. One of major findings from this study is that efficiency level of large SOEs are not so high as compared to smaller ones, suggesting ineffective government policy of merging large SOEs in this industry.

There are few studies working on the impact of IT on firm's performance, but some papers are addressing the relationship between R&D and productivity. Using data on 8341 industrial firms from national wide, Zhang, Zhang and Zhao (2003) attempts to investigate ownership's influence on research and development (R&D) and productivity efficiency. The main conclusion that drawn from the study is that the state sector has significantly lower R&D and productive efficiency than non-state sectors, and foreign firms perform better than domestic collective-owned and joint stock enterprises. Hu (2201) also shows positive link between private R&D and firm productivity while the direct contribution of government R&D to firm productivity is insignificant.

Jefferson et al. (2003) uses panel data set of Chinese large and medium-size industrial enterprises (LMEs) from National Bureau of Statistics of China (NBS) and the determinants of firm-level R&D intensity, the process of knowledge production and the impact of innovation on firm performance, finding positive contribution of R&D expenditure to new product innovation, productivity and profitability. Using the same rich data set, Hu and Jefferson (2004) investigates contribution of three technological advance, technology transfer, domestic R&D and foreign direct investment to productivity and knowledge production. Among the main findings of the study is that

technology transfer affects productivity only through its interaction with in-house R&D. Jefferson et al. (2004) also employs the same data set, but aims to document change in ownership of LMEs from 1994-1999, the link of performance with ownership and possible association of ownership with innovation activity, finding rapidly diversifying ownership structure during the period under view, with the role of SOEs being steadily retreating.

3. Data and descriptive statistics

In this paper, we analyze productivity performance of Chinese manufacturing firms in conjunction with market based economic reform and advancement of information technology. TFP growth of a firm with substantial change in its organization and governance mechanism is compared with that of a firm without such change to see how enterprise reform in China contributes to productivity growth. In addition, the complementarity of IT and organizational change for productivity is tested. It should be noted that this study analyzes relative performance of a firm with organizational change in manufacturing sector, instead of evaluating enterprise reform in China on its overall economic performance.

The dataset used in this paper is based on NBS's statistics on all large and medium sized enterprises (LMEs), which are used in Jefferson et al. (2003) and Jefferson et. al (2004). This dataset comes from NBS' survey on Science and Technology Activities., which is conducted for all LMEs in industrial sector from 1995 to 2002. In this survey, the data for Industrial output and input variables come from industrial statistics. There is also the variable of IT capital stock, including production facility controlled by IT, as well as conventional general purpose computers, from S&T survey. The LMEs are defined as firms with no less than certain amount of physical capacity of production. The threshold point varies by industry, and its unit corresponds to technical characteristics of each sector, such as 'ton' for some chemicals and 'sheets' for some textiles.[4] There are about 25,000 samples in each year.

First, descriptive statistics on ownership changes of Chinese industrial enterprises is provided according to this dataset. Table 1 shows ownership composition of value added by entire LMEs. Overall LMEs fall into seven group: (1) state-owned enterprises, (2) collective-owned enterprises, (3) Hong Kong, Macao and Taiwan-owned enterprises (HK-M-T enterprises), (4) foreign-owned enterprises, (5) shareholding enterprise, (6) private enterprises and (7) other enterprises. The most noticeable in the table is sharp

[4] For detailed discussion of definition of criteria, see Hu et al. (2004).

decline in share of SOEs in total value added for LMEs, from 73.3 percent in 1995 to 34.5 percent in 2002. Although differing in period and also in indicators, observation made here is roughly in line with those in other studies. Jefferson et al. (2004), for example, shows the proportion of the number of SOEs in total LMEs deceased from 67.9 percent in 1994 to 50.6 percent in 1999.

(Talble 1)

Behind the substantial decline of SOEs is large increase for shareholding enterprise, which share of value added in the total for all types of ownership rose from 6.8 percent from 1995 to 33.1 percent in 2002. The substantial rise in relative importance of shareholding enterprises principally reflects a result of enterprise reform that intends to convert the SOEs to shareholding enterprises. The foreign enterprise also gained its share during the same period, from 7.0 percent to 15.9 percent. Similar to the foreign enterprise, HK-M-T enterprises also doubled its share over the period, but its share in 2002 is below that of foreign enterprises by 6.0 percent, compared with by 2.6 percent in 1995. This suggests that foreign enterprises are outpacing HK-M-T enterprises. It should be also noted that collectives lost its share during the period under view, which indicates that the collectives, similar to SOEs, is contracting part in Chinese industry.

In order to get further understanding of relative importance of SOEs and its change, we show in Table 2 SOEs share of value added in the total by sector. It is evident from the table that with exception for very few sectors and very few years, the relative importance of SOEs has retreated for all sectors, of which, mining and petrochemical industry is more noticeable. That is, SOEs share in mining, in term of value added, dropped from 99.2 percent in 1995 to 31.7 percent in 2002. And the figures in petrochemical industry are from 96.0 percent to 22.7 percent for the same period. It should be also noted that the biggest drop in the two industries occurred recently yeas, say around 2000 and 2001. In the latest year of 2002, the only sector where share of SOEs in total value added is above half is Food and tobacco. Evidently, this is mainly due to the monopoly power of the state in production of tobacco.

(Table 2)

These drastic structural changes in Chinese manufacturing firms are coming from substantial changes in firm's organization and governance mechanism which are treated as entry and exit from this datasets. Table 3 shows the number of firms in our sample by type of firm's ownership. The number of state owned enterprises goes down from

15,718 in 1995 to 7,851. On the other hand, the growing sector is stock holding companies (from 965 to 6,030), T-HK-M firms (from 950 to 2,479) and foreign owned companies (from 1,058 to 3,016). Recently the number of private companies is also increasing.

(Table 3)

According to the firm registration system in China, when major restructuring in business lines as well as management resources was conducted, such firm has to be registered as a new firm. In a process of corporatising SOE, it is typical to conduct restructuring in its business. In addition, some of business of SOE may be merged with foreign capital to come up with new joint venture companies. All of these processes are tracked as entry and exit of enterprises in our samples. Therefore, it is reasonably to say that substantial amount of entries of exits of enterprises in our sample are consequences of enterprise reforms.

The diffusion of IT in Chinese manufacturing sector can be also analyzed based on this dataset. The 1990's is an era of IT revolution not only in developed countries, and also in developing countries including China. Tremendous technological progress in IT as well as advancement of Internet must have a non negligible impact on Chinese manufacturing firms. In our dataset, IT capital is defined as production facilities controlled by IT system. The definition is broader than conventional measures for IT, such as the stock of general purpose computers, software and communication equipment. Figure 1 shows a trend of the size of total capital stock and IT capital stock, as well as the ratio of IT stock to total stock. We can see consistent increase in the size of both capital stocks, while the IT intensity is declining after 1999 due to slower pace of IT capital stock growth.

(Figure 1)

Do all of these structural changes and IT diffusion lead to higher productivity performance at Chinese enterprises? In order to address this question, we use the following TFP index at each firm "i" and time "t".

$$\ln TFP_{i,t}^{j} = \ln VA_{i,t}^{j} - \overline{\ln VA_{i,t}^{j}} - sEMP_{t}^{j} \cdot (\ln EMP_{i,t}^{j} - \overline{\ln EMP_{i,t}^{j}}) - (1 - sEMP_{t}^{j}) \cdot (\ln CAP_{i,t}^{j} - \overline{\ln CAP_{i,t}^{j}}) \quad (1)$$

where VA, EMP and CAP are value added, number of employment and capital stock,

respectively for firm ‘i’ in year ‘t’. sEMP is the shares of labor compensation, i.e., the ratio of total wage to value added for industry ‘j’. It should be noted that the share is an industry average at 2 digit industry code. In addition, $\overline{X^{j}_{i,t}}$ is an average of X in industry ‘j’. This TFP index indicates relative productivity of each firm within each industry, and it is widely used in literature on the relationship between market dynamics of productivity. (Baily et. al, 1992)

Constant price value added is constructed by double deflation method, using output deflator for gross output and input deflator for intermediate inputs. Output deflators are taken from Chinese Statistical Yearbook, and input deflators are calculated by using 1997 benchmark IO table as weighted average of output deflators for each industry. Constant price capital stock is based on book value of capital stock for structure and machinery in 1995. Current price gross investment is estimated by the following equation.

$$CAP_{t+1,p=t} = \delta * CAP_{t,p=t} + I_{t+1,p=t}$$

$$= \delta * CAP_{t,p=t} + (CAP_{t+1,p=t+1} - \delta * CAP_{t,p=t}) / p_{I,t+1,p\sim t} \qquad (2)$$

where CAPt,p=s is constant price capital stock at year ‘t’ using the price at base year “s”, δ is the rate of depreciation and PI is investment price. Capital stocks for structure and machinery are estimated individually, assuming service life of structure for 40 years and machinery for 16 years. Investment prices for both type of capital are taken from Chinese Statistical Yearbook.

Moving to comparison between three types of enterprises, the exit, the entry and the continuous, for given period we defined the exit as those enterprises that exist in the starting year but disappeared in finishing year, while we define the entry as those don’t exist in the starting year but appeared in the finishing year. And naturally, the continuous are defined as enterprises that existing in both the starting and finishing years of the given period. Across these types of firms, the following three indicators on productivity and IT are compared.

- TFP: relative TFP index as is defined in equation (1)
- ITCAPD: dummy variable that takes 1 if the enterprise has IT capital stock and takes 0 if not (mean of this indicator shows the share of firms with IT capital)

- ITCAPR: a ratio of amount of IT capital stock to total capital stock, and it is zero if the enterprise has no IT capital stock at all.

Table 4 shows the relative value of these three indicators for the entry and the exit to the continuous. The calculation in the table is made by ownership of enterprise, aiming to see if the comparison varies by ownership of enterprise and also for three periods, 1995-98, 1999-2002 and 1995-2002.

(Table 4)

As can be seen from the table, with very few exceptions the TFP performance is lower in the exit and higher in the entry compared with the continuous enterprises. Therefore, enterprise reform such as an ownership change from SOEs to stock holding companies has conducted for relatively low productivity firm. In addition, it can be said that the firm after such reform is relatively higher in its productivity. In contrast to TFP, no clear pattern can be found in ITCAPD and ITCAPR.

(Table 5)

Similar comparison is made by industry in Table 5. Briefly speaking, the same patters observed for ownership are also observed for industry. That is, in almost all of sectors, the exit has lower TFP performance but the entry has higher TFP performance compared with the continuous. When comparison is made on the base of ITCAPD and ITCAPR, there is no clear pattern again. It is found that a firm with substantial reform has not used IT in its production process more intensively than a firm without, so that enterprise reform itself may know stimulate investment in IT. However, organizational changes with better governance mechanism of corporate performance may induce effective use of existing IT facilities. This relationship of IT, enterprise reform and productivity is analyzed in the following section.

4. Regression analysis

In this section, production function is estimated in order to analyze impact of IT and enterprise reform on productivity of Chinese manufacturing firms. By treating IT capital services explicitly in the production function framework, factor contribution of IT as well as its impact on factor neutral TFP can be evaluated. The following Cob Douglas production function with error component structure is considered as a base.

$$\ln VA_{it} = \alpha_{IT} \ln IT_{it} + \alpha_{nonIT} \ln nonIT_{it} + \alpha_{EMP} \ln EMP_{it} + u_{it} \qquad (3)$$

$$u_{it} = a_{it} + e_{it} + \varepsilon_{it}$$

where VA, IT, non-IT and EMP is constant price value added, IT capital stock, non-IT capital stock and number of employment, respectively. Error terms of equation (3) can be decomposed into a_{it} : firm specific factors for firm's performance, such as managerial capabilities and workers' motivation, e_{it} : exogenous shocks for firm's performance, such as macro economic business cycle, and ε_{it} :error terms associated with measurement errors. Typically, a better firm invests more and employs more, a_{it} is positively correlated to explanatory variables, so that their coefficients have upward bias when equation (3) is estimated by OLS. In this case, a fixed effect model by assuming a_{it} as time invariant components ($a_{it} = a_i$), is commonly used. (Griliches and Mairesse, 1995)

In order to capture the impact of IT and enterprise reform on productivity, an equation (3) is extended to the following as models to be estimated in this section.

$$\ln VA_{it} = \alpha_{IT} \ln IT_{it} + \alpha_{nonIT} \ln nonIT_{it} + \alpha_{EMP} \ln EMP_{it} + \beta_{ent} * Ent * t + \beta_{exit} * Exit * t + \gamma_{ent} Ent * ITCAPR_{it} + \gamma_{exit} Exit * ITCAPR_{it} + u_{it} \quad (4)$$

$$u_{it} = a_i + e_{it} + \varepsilon_{it}$$

As in shown in the previous section, enterprise reform such as corporatising state owned enterprises can be captured as exit of SOE and entry of stock holding enterprise in this dataset. While it is impossible to link between exiting firm and entry one, enterprise reform can be evaluated by comparing entry and exit firms to continuing ones. In equation (4) ENT is a dummy variable whether a firm enters the observations from 1995 to 2002. On the other firms, EXIT is a dummy variable for a firm's exit from the observations during the same period. Both dummy variables are multiplied by time trend "t", in order to keep these dummies even after fixed effect transformation. Therefore, βs reflect the difference of TFP growth, instead of level, as compared to continuing firms for all periods of panel dataset. Equation (4) also has explanatory variables of cross terms of these dummies with ITCAPR, which is the ratio of IT capital stock to total capital stock These cross terms can capture the degree of complementarity or substitutionality of IT and enterprise reforms for productivity.

Regression results using all samples are shown in Table 6. Model (1) to Model (3) are results from basic specifications, as is described in equation (1). It is found that IT capital contributes significantly to value added. When comparing model (2) and model (3), the output elasticity of IT capital increases over time. Coefficients of model (2) and (3) are relatively smaller than those of model (1). Fixed effect transformation of panel data can cause downward bias to estimated coefficients with measurement errors, and

such bias become larger for shorter panel in general (Griliches and Hausman, 1984). This may be the case for our estimates as well.

(Table 6)

In model (4)-(6), only dummies for entry and exit are added to model (1)-(3). As is shown in Model (4), entry firms outperform continuing ones by TFP growth, while exit firms are in slower productivity growth. This finding suggests enterprise reforms, in a sense of shutting down of low productivity firms, and ownership reforms of the other firms, have worked. Furthermore, it is found that the impact of exit of lower productivity firms is larger in the first half, while contribution of entry firms on productivity growth can be particularly found in the later half of this sample.

Finally, model (7)-(9) are full models using equation (2). Sings of coefficients to ENT and EXIT are almost same as those of model (4)-(6). One of major findings from these models is a positive and significant coefficient to the cross term of entry and IT intensity (ITCAPR). Entry contributes to TFP positively, and the degree of this positive impact becomes larger when this firm's IT intensity is higher. In this sense, enterprise reform and IT are complementary to productivity growth at firm level. This is consistent to our hypothesis that efficiency gain from IT needs proper incentive mechanism to achieve higher productivity. Enterprise reform via corporatising SOEs and joint venture with foreign own companies, is essential to have the power of IT enable to be shown up.

In order to look into this point in mode detail, Table 7 gives regression result of equation (4) by type enterprise ownership. First, positive and significant coefficients to ITCAP can be found all types, except for T-HK-M firms and private ones. According to high coefficients to EMP for T-HK-M firms, they concentrate in labor intensive industry, where the role of IT is relatively small. Private firms are emerging recently, and there may be a problem with small sample size.

(Table 7)

On the other hand, entry firms achieved higher productivity performance in all categories. In addition, exit firms are lower in the productivity growth, except for private firms. It can be said that enterprise reforms captured by entry and exit in our samples contribute to productivity growth in Chinese manufacturing industries. As for the cross term of ENTRY with ITCAPR, positive and significant coefficients can be found in SOEs and stock holding companies. For these companies, as well as contribution of entry of new firms, they achieved better productivity performance, as IT

intensity becomes higher. Positive coefficients can be found in collective, foreign owned and private firms, but they are not statistically significant.

Table 8 shows the same regression result by industry and location of firms. 14 types of industry classification in Table 2 are aggregated three types. The first category is state owned sector including mining, petrochemical, primary metals and utilities. These heavy and energy related industries used to be managed by the state, and has been gone through SOE reforms. The second one is machinery sector, including fabricated metals, general machinery, transportation equipments, electrical and electronics, which are relatively new and not so heavily regulated industries. Finally, the third one includes the other industries. In model (5) and (6), all samples are divided into urban and local group, and regressions are conducted separately. Urban group includes firms located in Beijing, Tianjin, Hebei, Shanghai, Jiangsu, Zhejiang and Guangdong, and local groups are those in the rest of region.

(Table 8)

In all types of industry, IT capital has a positive and statistically significant coefficient. The size of output elasticity is larger for machinery sector, due to its higher IT capital intensity. It is also found that ENTRY firms achieved higher productivity growth than continuing ones. It should be noted that this is the case for state sector, where entry and exit of enterprises are, presumably, associated with SOE reforms in most cases. On the other hand, there should be substantial green field entries in machinery sector, so that positive coefficients with ENTRY in model (2) may come from these new entrants. In all models, the cross term of ENTRY and ITCAPR is positive. Although statistically significant coefficient at 5% level can be found only in other manufacturing group, it should be noted that the other two are significant at 10% level. As for regional breakdown, there cannot be found a big difference. IT capital's contribution to value added, productivity effect of entry and exit, and complementarity of enterprise reform and IT can be found both in urban and local areas.

5. Conclusion

In this paper, the impact of enterprise reforms and IT on productivity is investigated by using micro-data for Chinese manufacturing firms from 1995 to 2002. In our dataset, substantial enterprise reforms, typically happened in SOE reforms such as corporatizing as well as joint venturing with foreign capitals, can be captured by entry of exit of firms. Tremendous structural changes in terms of firm's ownership can be observed in Chinese manufacturing sector, which is driven by entry and exit of firms, instead of relative

importance of continuing firms. It is found that exiting firms (pre-reform firms) are lower in productivity than continuing ones, while entering firms (post-reform firms) are higher. Therefore, it can be said that enterprise reforms in China has a positive impact on aggregated productivity growth.

On the other hand, the IT intensity in entry firms is not always higher than that of continuing firms. Production facility of post reform enterprises is not so modern at the outset. However, complementarity of IT and enterprise reform for productivity can be found. One of interpretation of this finding is that post reform enterprises have better incentive structure to improve productivity by using information technology. Or, another interpretation can be post reform enterprises are better equipped with intangible capital for efficient use of IT, such as performance based incentive system and flatter organizational structure. Identification of factors behind this complementarity between entry reform and IT needs further investigation on micro structure of enterprises.

References

Baily, M. N., C. Hulten, and D. Campbell (1992): "Productivity dynamics in manufacturing plants." *Brookings Papers on Economic Activity, Microeconomics*, 187-267

Brynjolfsson, E. and L. Hitt (2000), "Beyond Computation: Information Technology, Organizational Transformation and Business Performance," *Journal of Economic Perspectives*, Vol. 14, No. 4, Fall, pp. 23-48.

Griliches, Z. and J. Hausman (1984), Errors in Variable in Panel Data, *Journal of Econometrics* 31, 93-118

Griliches,Z. and J. Mairesse (1995), Production Functions: The Search for Identification, NBER Working Paper No. 5067

Hu, Albert G. Z. and Gary H. Jefferson (2004), 'R&D and technology transfer: firm-level evidence from Chinese industry,' mimeo, http://people.brandeis.edu/~jefferso/res.html.

Jefferson, Gary and Tholmas G. Rawski (1994), 'Enterprise reform in Chinese industry,' *Journal of Economic Perspectives,* Vol. 8, No.2, pp. 47-70

Jefferson, Gary H., Tholmas G. Rawski, Wang Li and Yuxin Zheng (2000), "Ownership, productivity change, and financial performance in Chinese industry," *Journal of Comparative Economics*, 28, 4: 786-813

Jefferson, Gary H., Bai Huamao, Guan Xiaojing and Yu Xiaoyun (2003), 'R and D

performance in Chinese industry,' mimeo, http://people.brandeis.edu/~jefferso/res.html.

Jefferson, Gary H., Albert G. Z. Hu, Guan Xiaojing and Yu Xiaoyun (2004), 'Ownership, performance, and innovation in China's large and medium-size industrial enterprise sector,' forthcoming in *China Economic Review*

Jorgenson, D. W. and K. Motohashi (2005), Information technology and the Japanese economy, forthcoming *Journal of Japanese and International Economies*

Motohashi, K (2003), Firm level analysis of information network use and productivity in Japan, RIETI Discussion Paper 03-E-021, Tokyo, Research Institute of Economy, Trade and Industry

Movshuk, O. (2004), Restructuring, productivity and technical efficiency in China's iron and steel industry, 1988-2000, *Journal of Asian Economies* 15 (2004), 135-151

OECD (2003), *ICT and Economic Growth: Evidence from OECD countries, industries and firms*, OECD Paris

Qu, Qaing (2003), 'Corporate governance and state-owned shares in Chinese listed companies,' *Journal of Asian Economics*, 13 pp. 771-83

Watanabe, Mariko (2002), 'Holding company risk in China: a final step of state-owned enterprises reform and an emerging problem of corporate governance,' *China Economic Review,* 13, pp. 373-81.

Zhang, A., Zhang Y. and R. Zhao (2001) "impact of ownership and competition on the productivity of Chinese enterprises," *Journal of Comparative Economics* 29, 2:327-46

Zhang, A., Zhang Y. and R. Zhao (2003), "a study of the R&D efficiency and productivity of Chinese firms," *Journal of Comparative Economics* 31 (2003) 444-464

Zheng, J., Liu X. and A. Bigsten (2001) 'Efficiency, technical progress, and best practice in Chinese state enterprise (1980-1994),' *Journal of Comparative Economics*, 31, pp. 134-52

Zhu, T. (1999), China's corporatization drive: an evaluation and policy implication, *Contemporary Economic Policy* 17, 530-539

Table 1: The change in ownership composition of value added from 1995 to 2002

ownership	1995	1996	1997	1998	1999	2000	2001	2002
State-owned	73.3	70.1	67.8	64.0	59.3	46.9	36.3	34.2
Collective-owned	7.9	9.5	8.5	8.1	7.8	6.8	5.3	4.7
HK, M, TW	4.3	5.1	5.5	6.4	7.2	7.4	9.4	9.9
Foreign	7.0	7.6	8.5	9.0	10.6	11.6	14.6	15.9
Stockholding	6.8	7.1	9.0	11.9	14.2	26.2	32.5	33.1
Private	0.0	0.0	0.1	0.3	0.7	0.8	1.5	2.0
Others	0.6	0.6	0.6	0.3	0.2	0.2	0.2	0.2

Table2: Shares of state-owned enterprises in total value added by industry

industry	1995	1996	1997	1998	1999	2000	2001	2002
Mining	99.0	96.6	96.5	97.9	96.2	51.1	22.6	31.7
Food and tabacco	81.4	79.6	78.7	73.7	67.7	60.6	57.1	60.4
Texitile	51.6	43.3	44.5	40.7	35.4	32.9	24.3	20.8
Leather, paper, wood	52.6	46.1	40.8	36.2	29.6	27.3	20.4	17.2
Petrochemical	96.1	92.7	90.7	90.6	87.3	58.5	32.4	22.9
Chemical (exc. Drugs)	60.7	58.1	52.9	46.1	42.9	38.3	32.2	24.6
Drug	54.8	51.6	47.0	42.9	42.3	33.3	27.4	13.4
Primary metals	80.1	79.0	79.7	74.6	68.7	59.4	55.4	46.5
Fabricated metals	34.6	34.6	32.7	29.7	27.4	22.8	16.5	13.5
Machinery	64.9	64.4	59.9	50.1	46.3	39.6	32.5	28.3
Transportation	66.9	60.6	60.2	55.4	51.2	45.7	42.2	33.3
Electrical and electronics	32.7	35.0	26.3	29.7	19.3	18.2	10.6	12.8
Other manufacturing	5.5	12.8	7.1	7.3	5.7	9.7	2.0	-4.0
Utilities	83.0	79.9	74.2	71.4	70.0	68.4	63.0	59.0

Table3: the number of enterprises by ownership from 1995 to 2002

ownership	1995	1996	1997	1998	1999	2000	2001	2002
State-owned	15,718	15,085	14,409	13,177	11,011	10,125	8,857	7,851
Collective-owned	4,022	4,230	4,126	3,596	3,345	3,087	2,482	2,201
HK, M, TW	950	1,142	1,217	1,456	1,527	1,584	2,220	2,479
Foreign	1,058	1,355	1,548	1,593	1,947	2,117	2,664	3,016
Stockholding	965	1,109	1,724	2,757	3,378	4,092	5,500	6,030
Private	4	14	34	173	308	476	936	1,263
Others	287	290	288	210	155	175	126	149

Table 4: Comparison of TFP and IT investment between the exit, the entry and the continuous by ownership of enterprises

Periods	Type of enterprise	Variables	SOE	Collective	T-HK-M	Foreign	Sharehold	Private	Others
1995-98	the Exit	TFP	-0.062	0.017	0.115	-0.086	-0.031	0.103	0.139
		ITCAPD	-0.050	-0.039	-0.141	0.038	-0.088	0.000	0.250
		ITCAPR	-0.011	-0.013	-0.122	-0.010	-0.009	0.000	0.078
	the Entry	TFP	0.163	0.123	-0.019	0.177	0.079	0.202	0.552
		ITCAPD	-0.113	-0.014	-0.170	-0.192	-0.201	0.214	0.005
		ITCAPR	-0.012	0.003	-0.042	-0.020	-0.042	0.011	0.083
1999-2002	the Exit	TFP	-0.183	-0.019	-0.088	0.210	-0.039	0.237	0.107
		ITCAPD	-0.105	-0.051	0.010	0.076	-0.096	-0.063	-0.228
		ITCAPR	-0.003	-0.018	-0.098	0.022	-0.032	-0.028	-0.009
	the Entry	TFP	0.089	0.369	0.204	0.105	-0.106	0.141	0.315
		ITCAPD	-0.089	-0.208	-0.082	-0.045	0.083	0.114	-0.334
		ITCAPR	0.028	-0.064	-0.042	-0.001	-0.033	0.030	-0.007
1995-2002	the Exit	TFP	-0.186	-0.031	0.112	-0.042	-0.208	0.103	-0.025
		ITCAPD	-0.100	-0.070	-0.186	0.222	-0.094	0.000	0.048
		ITCAPR	-0.007	-0.005	-0.177	-0.052	-0.009	0.000	0.060
	the Entry	TFP	0.027	0.302	0.006	0.100	-0.101	1.498	0.075
		ITCAPD	0.030	-0.079	-0.171	-0.165	-0.070	0.427	-0.157
		ITCAPR	0.017	-0.002	-0.059	-0.017	-0.044	0.070	-0.032

Table 5: Comparison of TFP and IT investment between the exit, the entry and the continuous by sector between 1995-2002

Industry	the Exit			the Entry		
	TFP	ITCAPD	ITCAPR	TFP	ITCAPD	ITCAPR
Mining	-0.4600	0.0396	0.0056	0.1632	0.2173	-0.0414
Food and tabacco	0.0075	-0.0308	-0.0667	-0.0775	0.1012	-0.0138
Texitile	-0.1672	-0.0732	-0.0052	0.1730	-0.0329	-0.0046
Leather, paper, wood	-0.1397	-0.2029	-0.0440	0.0494	-0.0689	-0.0544
Petrochemical	-0.4134	-0.1453	-0.0367	0.3500	-0.0069	0.0745
Chemical (exc. Drugs)	-0.1828	-0.1444	0.0193	0.2047	-0.0859	0.0327
Drug	-0.1919	0.0847	0.0304	-0.2263	0.2323	-0.0153
Primary metals	-0.0145	-0.1913	-0.0050	0.3073	-0.0026	0.0224
Fabricated metals	-0.1580	-0.1388	0.0048	0.0977	-0.0615	0.0181
Machinery	-0.0438	-0.1048	-0.0134	0.2434	-0.1164	0.0160
Transportation	-0.0456	-0.1806	0.0060	0.4124	-0.2657	0.0622
Electrical and electronics	-0.0959	-0.0035	-0.0432	0.1987	-0.1812	-0.0265
Other manufacturing	0.0289	-0.0523	-0.0268	0.2535	0.0344	-0.0727
Utilities	-0.0079	0.0185	-0.0654	-0.0584	-0.0629	0.0059

Table 6: Regression results for all samples

	(1) All	(2) year=<98	(3) year>=99	(4) All	(5) year=<98	(6) year>=99	(7) All	(8) year=<98	(9) year>=99
emp	0.322	0.431	0.289	0.336	0.410	0.312	0.333	0.410	0.308
	(27.23)**	(17.97)**	(15.52)**	(28.01)**	(16.97)**	(16.71)**	(27.66)**	(16.96)**	(16.47)**
itcap	0.045	0.016	0.034	0.041	0.020	0.028	0.034	0.019	0.019
	(17.11)**	(3.69)**	(8.03)**	(15.31)**	(4.48)**	(6.64)**	(11.65)**	(3.99)**	(3.91)**
nonitcap	0.248	0.139	0.198	0.232	0.163	0.176	0.251	0.164	0.203
	(30.30)**	(9.09)**	(16.30)**	(27.87)**	(10.29)**	(14.42)**	(27.54)**	(9.67)**	(14.65)**
entry*t				0.058	0.004	0.072	0.057	0.005	0.071
				(15.63)**	(0.27)	(12.30)**	(15.17)**	(0.34)	(12.04)**
exit*t				-0.020	-0.041	-0.012	-0.021	-0.041	-0.012
				(4.93)**	(5.64)**	(0.87)	(5.10)**	(5.66)**	(0.88)
entry*itcapr							0.255	-0.130	0.270
							(4.66)**	(0.92)	(3.85)**
exit*itcapr							0.107	0.056	0.103
							(1.60)	(0.57)	(0.81)
Constant	4.604	5.064	5.663	4.621	4.938	5.592	4.468	4.936	5.367
	(39.04)**	(22.32)**	(31.32)**	(39.30)**	(21.68)**	(30.96)**	(36.86)**	(21.19)**	(28.46)**
Observations	63916	30139	33777	63916	30139	33777	63916	30139	33777
Number of id	23942	15365	16475	23942	15365	16475	23942	15365	16475
R-squared	0.05	0.03	0.03	0.06	0.03	0.04	0.06	0.03	0.04

Absolute value of t statistics in parentheses
* significant at 5%; ** significant at 1%

Table 7: Regression results by type of firm ownership

	(1) SOE	(2) Collective	(3) T,HK,M	(4) Foreign	(5) Stock	(6) Private
emp	0.229	0.438	0.609	0.545	0.406	0.482
	(13.49)**	(12.67)**	(10.30)**	(11.29)**	(13.54)**	(4.98)**
itcap	0.029	0.041	0.014	0.073	0.017	-0.021
	(7.26)**	(4.79)**	(0.95)	(6.12)**	(2.11)*	(0.54)
nonitcap	0.288	0.210	0.071	0.196	0.227	-0.009
	(21.20)**	(7.40)**	(2.17)*	(6.81)**	(9.77)**	(0.08)
entry*t	0.043	0.049	0.061	0.096	0.046	0.091
	(7.02)**	(4.41)**	(3.83)**	(7.49)**	(5.77)**	(2.49)*
exit*t	-0.026	-0.004	-0.064	-0.046	-0.006	0.094
	(4.74)**	(0.35)	(2.61)**	(1.96)*	(0.45)	(1.14)
entry*itcapr	0.325	0.085	-0.165	0.097	0.319	0.069
	(2.94)**	(0.54)	(0.96)	(0.68)	(2.61)**	(0.14)
exit*itcapr	0.181	0.134	0.120	-0.403	0.343	0.047
	(1.74)	(0.83)	(0.52)	(1.81)	(1.89)	(0.04)
Constant	4.651	4.139	5.342	3.959	4.596	6.529
	(25.13)**	(12.23)**	(10.63)**	(9.71)**	(15.66)**	(5.04)**
Observations	34613	7532	4062	5364	10859	960
Number of id	12527	3538	1934	2395	5269	669
R-squared	0.04	0.08	0.06	0.11	0.07	0.12

Absolute value of t statistics in parentheses
* significant at 5%; ** significant at 1%

Table 8. Regression results by industry and location

	(1) State	(2) Machinery	(3) Other	(4) Urban	(5) Local
emp	0.319	0.329	0.336	0.433	0.250
	(11.29)**	(17.81)**	(17.13)**	(24.67)**	(15.23)**
itcap	0.028	0.049	0.026	0.036	0.032
	(4.83)**	(9.28)**	(5.81)**	(8.10)**	(8.21)**
nonitcap	0.264	0.256	0.234	0.223	0.277
	(14.83)**	(15.98)**	(16.45)**	(17.50)**	(21.42)**
entry*t	0.032	0.089	0.042	0.064	0.049
	(4.16)**	(13.84)**	(7.18)**	(12.07)**	(9.37)**
exit*t	-0.020	-0.033	-0.011	-0.025	-0.017
	(2.44)*	(4.81)**	(1.63)	(4.16)**	(3.04)**
entry*itcapr	0.260	0.160	0.307	0.136	0.385
	(1.86)	(1.73)	(3.89)**	(1.88)	(4.61)**
exit*itcapr	0.161	0.087	0.097	0.095	0.113
	(0.87)	(0.76)	(1.04)	(1.05)	(1.15)
Constant	4.516	4.208	4.767	4.232	4.665
	(17.13)**	(20.58)**	(25.21)**	(24.72)**	(27.38)**
Observations	14306	24123	25487	27622	36294
Number of id	5071	8485	10566	10138	13807
R-squared	0.05	0.06	0.05	0.07	0.05

Absolute value of t statistics in parentheses

* significant at 5%; ** significant at 1%

Figure 1: Trend of capital stock and IT capital stock