Will Science and Technology Solve China's Unemployment Problem?*

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Abstract
China needs a substantial growth of modern-sector employment to absorb its huge supply of underemployed people and new labor market entrants. The present crisis with its massive layoffs of workers makes the issue even more pressing. Although the government has announced large public investments to deal with the business cycle downturn, less attention has been paid to the structural aspects of Chinese underemployment. One exception is the recent emphasis of technology development. However, science and technology (S&T) can have both positive and negative effects on employment. Using information from a large sample of manufacturing firms in China between 1996 and 2004, we analyze how S&T affects employment. Our results suggest that S&T does not promote employment growth.

1. Introduction

China has weathered the current global economic crisis well: large public investments and stimulus packages have enabled growth to remain relatively high. However, the recent massive layoffs of workers, primarily in the manufacturing sector, are of concern because these layoffs hit a labor market that was in distress even before the crisis hit.

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China suffers from a chronic inability to create jobs for an underemployed and growing workforce, and not enough attention has been paid to the structural aspects of Chinese underemployment (Hu 2004). One exception is the emphasis on technology development. Over the last few years, the Chinese government has promoted science and technology (S&T) heavily, stressing technological change in general and indigenous technological change in particular (Chinese Ministry of Science and Technology 2006; Sjöholm and Lundin 2010). More recently, in August 2009 Science and Technology Minister Wan Gang argued again, "The most effective way to withstand the impact of the global economic meltdown is to accelerate technological innovation, the new economic growth engine."[1] Chinese firms have responded to the official rhetoric; today, China is one of the world's largest investors in science and technology (OECD 2005).

Policymakers expect increased efforts in science and technology to improve the competitiveness and the growth rate of the Chinese economy. Less discussed is the effect of science and technology on employment, and this neglect is unfortunate because of the serious lack of jobs in the formal sector.

Exactly how science and technology will affect employment is unclear. On the one hand, it could enhance competitiveness and thereby increase demand for labor; on the other, it could lead to skill- or capital-intensive production and thereby reduce demand for labor. The dominant mechanism is still open to discussion.

Our analysis of the relationship between S&T and employment draws on a data set that covers all large- and medium-sized enterprises in the Chinese manufacturing industry between 1998 and 2004. One methodological concern is that we can only observe employment in surviving firms and survival might be affected by S&T. The results on how S&T affect employment could therefore be biased. Yet even after using the Heckman two-step estimation procedure to control for the higher survival rate of firms engaged in S&T, the data show no positive effect on growth in employment. Our conclusion is that technology development does not seem to solve one of China's most important policy issues: insufficient employment opportunities.

2. S&T and employment—a conceptual framework and previous studies

Progress on the S&T front has both positive and negative impacts on employment. The positive impact is mainly caused by the effect of S&T on firms' survival and growth. More specifically, firms conduct S&T to improve existing production pro-

1 "Government Pledges Strong Support for Innovation-based SMEs." *China Daily,* 1 September 2009.

cesses and products, or to develop new ones. New products and processes will result in productivity gains through improved efficiency in production (lower costs) or through higher prices on output (new products). Improved productivity benefits the firm in terms of higher competitiveness and thereby increases its chances of surviving in the market and expanding its activities.

There are also theories suggesting that some technological change might be negative for employment. More precisely, the literature on skill-biased technological change suggests that technology and labor (or some types of labor) might be substitutes rather than complements. This means that improved technology might, for instance, make the firm use more capital but less labor, or more skilled labor but less unskilled labor (e.g., Thoenig and Verdier 2003; Ekholm and Midelfart 2005).

Turning to the empirical literature, the positive relationship between S&T and productivity is well documented and need not be elaborated on further.[2] There is also ample evidence of a positive effect of productivity on firms' growth and survival. For instance, Okamoto and Sjöholm (2005) examine productivity growth in Indonesia and find a strong effect on aggregate productivity from increases in market shares by plants with relatively high productivity growth. Accordingly, Levinsohn and Petrin (1999) find a similar mechanism in Chile with growth of market shares for firms with high productivity.[3] Survival is also closely related to productivity: firms exiting the market tend to have relatively low levels of productivity.[4] It should be noted that firm growth is not automatically associated with growth in employment. Moreover, high productivity can be caused, of course, by factors other than S&T.

Most empirical studies on technology and employment examine changes in the demand for skilled and unskilled labor, typically in developed countries. There seems to be substantial evidence of skilled-biased technological change, irrespective of differences in methodologies and countries (Berman, Bound, and Machin 1998; Hollander and ter Weel 2002; Kang and Hong 2002; Bauer and Bender 2004; Ochsen and Welsch 2005; Xiang 2005). Whether skill-biased technological change will reduce total employment depends on two factors. First, the change in relative prices (wages for skilled and unskilled labor) will have an impact on the changes in the number of employees. If, for instance, the relative price of unskilled labor falls, this will miti-

2 See, for example, Wieser (2005) for a recent survey of the literature on R&D and firm productivity.

3 See also Olley and Pakes (1996) and Foster, Haltiwanger, and Krizan (1998) for similar findings in developed economies.

4 See, for instance, various chapters in the book by Roberts and Tybout (1996).

gate the negative effect on employment of unskilled labor. Second, changes in the relative demand for different types of workers decrease the total number of employees only if the loss of unskilled workers is larger than the increase in skilled workers.

The studies here mentioned are concerned with issues that are only related to the focus of our paper. We intend to examine the effect of S&T, rather than that of productivity, on total employment, rather than on the composition of employment. Although, to the best of our knowledge, no such study has been conducted previously on developing countries, there are a few studies on developed countries. For instance, Van Reenen (1997) examines the effect of innovations on employment in a panel of 598 British firms. The results show a positive effect of innovations on employment, which is robust to changes in specifications. Moreover, Smolny (1998) examines the effect of process and product innovations on a panel of 2,405 German firms. Once more, there is evidence of a strong positive effect of innovation on employment.[5]

3. The Chinese context

The global economic crisis, starting in 2008, has lowered the demand for Chinese goods, and consequently, Chinese exports. As a result, the demand for workers has fallen and large numbers of migrant workers are reported to have lost their jobs. Although the exact figures are yet unclear, reports suggest the figure to be somewhere between 20 and 23 million, out of a population that in 2008 included between 130 and 140 million migrant workers (see Ye and Batson 2009 for a discussion).

The Chinese government has responded to the crisis by launching a major stimulus package of about 4 trillion yuan in November 2008 and by additional packages, such as a health insurance reform of about 850 billion yuan. A large part of the stimulus focuses on infrastructure projects. This will presumably offset some increase in unemployment caused by the decline in exports. The leadership remains concerned that the efforts will not be sufficient, and there have been frequent claims during 2009 that at least 9 million new urban jobs are needed urgently.

It should be noted that the crisis hits a labor market that is already in large difficulties: there was a serious lack of jobs in the formal market already before the crisis (Hu 2004; Démurger et al. 2006). The structural problems are not seen in official

5 There are also other studies on technology change and employment in industrialized countries conducted at a more aggregated level. Most studies find a positive effect of technology change on employment. See Pianta (2006) for a survey of the literature.

statistics: registered urban unemployment increased between 1995 and 2007 but only from 2.9 to 4 percent of the labor force (National Bureau of Statistics 2006, 2008). However, the official figures only include urban residents between ages 16 and 50 (16 and 45 for women) who register as unemployed. Urban residents who do not register are not included, nor are rural residents and migrant workers. Knight and Xue (2006) use adjusted official data and household data to estimate a more accurate urban unemployment rate. Their estimates suggest that urban unemployment amounted to above 11 percent in 2001, as compared to the official figure of 3.6 percent. Lee (2000) cites different sources and comes up with a similar figure: urban unemployment in 1996 is estimated at about 13 percent. Finally, Giles, Park, and Zhang (2005) use survey data for five large cities and find the urban unemployment rate to be about 14 percent in 2002.

The situation in the rural areas is likely to be even more troublesome but with sizeable underemployment rather than unemployment. For instance, almost one third of the rural labor force are claimed to be "surplus agricultural workers": workers that can leave agriculture with little negative impact on output (Lee 2000; Knight and Xue 2006). A large pool of underemployed workers depresses wages, as evidenced by low and declining shares of wages in value-added. For instance, the World Bank (2007) shows that the wage shares in value-added has declined from 53 percent in 1998 to 41.4 percent in 2005. As a comparison, the corresponding share was 57 percent in the United States in 2005.

Related to this issue is the large pool of Chinese workers in the informal sector. For instance, around 65 percent of China's internal migrants are without *hukou* (household registration) and are therefore excluded from the formal job markets (Cai, Wang, and Du 2005). A final sign of a deteriorating labor market is the large decline in the labor force participation rate from over 80 percent in 1996 to 71 percent in 2005 (Vodopivec and Tong 2008).

The need for employment growth is stressed by the continued growth of the labor force, which is predicted to grow at least until 2015 (Chow et al. 1999, p. 483; Cai and Wang 2006), and there is an expected 24 million new entrants to the labor force in 2009 alone.

Which Chinese firms will then be likely to provide the new jobs? There is strong evidence that firm ownership is important for employment (Karlsson et al. 2009). For instance, one main reason for the insufficient growth in modern sector employment in China is that the private sector, including foreign-owned multinationals and joint ventures, has difficulties in absorbing the same number of workers that are laid off from state-owned enterprises (SOEs). Employment in SOEs went from a peak of

145 million in 1995 to about 75 million in 2005 (Vodopivec and Tong 2008). Around 80–90 percent of these laid-off workers have moved to (small) private companies or are engaged in self-employment, in particular in the informal sector (Giles, Park, and Cai 2006; Vodopivec and Tong 2008). Hence, private domestic and foreign-owned firms are relatively more likely to generate jobs than are SOEs.

Of other firm characteristics that affect employment, firm size might be an important factor. In a study of the manufacturing sector in Shanghai, Chow et al. (1999) find small firms to be relatively able to generate jobs over the period 1989 to 1992. This situation is likely to be present today and in other parts of China, considering that the share of manufacturing employees in small firms has increased from 38.6 percent in 2000 to 49.5 percent in 2004.[6]

Referring to our issue of the impact of technology on employment, there are hardly any previous studies that can be consulted. It has been shown that large firms (many employees) conduct more S&T than small firms (few employees) (Sjöholm and Lundin 2010) but we cannot draw any conclusions from this stylized fact regarding the causality between S&T and employment growth. In other words, it might be that large firms are more willing to invest in S&T and thus, it is not a causal effect from S&T to employment growth.

4. Data and descriptive statistics

4.1 Data

Our data are on large- and medium-sized enterprises in the Chinese manufacturing sector over the period 1998–2004 and has been complied by the National Bureau of Statistics of China.[7] The classification of large- and medium-sized firms is based on a combined firm-size indicator, where employment, turnover, and fixed assets are taken into account.[8]

The included variables are from two different sources. The first source is balance sheets of firms from the Chinese industrial statistics; the other is S&T statistics. Merging these two data sets and using unique firm identification codes, we obtain a data set with two categories of variables: (1) firm-level economic variables, such as employment, wages, sales, value-added, profit, exports, fixed assets, time of estab-

6 The authors' own calculation, based on information complied by National Bureau of Statistics of China.

7 See also Xiao (2005, pp. 65–66) for a discussion of the data.

8 See Table A1 in the Appendix for the detailed classification.

lishment, and ownership, and (2) technology-related variables including S&T and R&D expenditures, human resource inputs such as S&T personnel and R&D personnel, and purchase of foreign technology.

4.2 Industry and ownership classifications

The industry classification is similar to the International Standard Industrial Classification, Rev. 3 classification. When output data, such as value-added and sales, are deflated into real values, the deflators are based on either the three-digit or the four-digit producer price deflators, depending on availability.

Furthermore, following the OECD classification, we divide the data set into high-tech and non-high-tech industries (Hatzichronoglou 1997; OECD 2005). The high-tech industries include aircraft and spacecraft; pharmaceuticals; office, accounting, and computing machinery; radio, television, and communications equipment; and medical, precision, and optical instruments. It should be stressed that products and processes in firms in a high-tech industry do not necessarily have high-technology content. This is particularly true for non-OECD countries such as China, and is due to differences in the industrial structure as compared to OECD countries (e.g., the dominance of labor-intensive processes in manufacturing).

Finally, for a comparison across various ownership groups, we follow the ownership classification applied by Jefferson et al. (2003) and Hu, Jefferson, and Jinchang (2005) in their previous analyses of S&T activities in Chinese large- and medium-sized enterprises (LMEs).[9]

4.3 Other data issues

S&T and R&D expenditures are two key measures on technology development used in our study. According to the commonly used international classification from the OECD, these two concepts are defined as follows (OECD 2002).

> **S&T:** systematic activities, which are closely concerned with the generation, advancement, dissemination, and application of science and technology. These include such activities as Research and Experimental Development (R&D), Science and Technical Education and Training (STET), and Scientific and Technological Services (STS).
>
> **R&D:** comprise creative work undertaken on a systematic basis to increase the stock of knowledge, including knowledge of man, culture, and society and the use of this stock of knowledge to devise new applications. The term R&D

9 See Appendix A2 for the detailed classification.

covers three activities: basic research, applied research, and experimental development.

In the current indicator system in China, the definition of R&D is in line with the *Frascati Manual.* International classifications of S&T indicators are less straightforward and the Chinese classification is no exception. The definition of S&T followed the UNESCO manual when the Chinese S&T statistics system was first introduced in the mid-1980s. In the last two decades, the definition of S&T has changed more toward the *Frascati Manual* recommendation. S&T in the Chinese indicator system includes R&D, technology acquisition (licenses) and renovation, and miscellaneous expenditures on preparation for the production of new products and applications of R&D results. Hence, S&T include several activities not included in R&D. We will therefore primarily use S&T in our analysis because we want to analyze how technology development in a broad sense affects employment. R&D expenditures will be used as a robustness check in parts of the analysis.

Another important definition is that of firm survival. Using the firm identification code, we define firm survival as when the firm's identification code remains in the data set and likewise, the "death" of the firm is defined as when the firm code disappears from the data set. However, it is difficult to distinguish between natural market exit (bankruptcy) and other reasons for firms to disappear from the data set. More specifically, the identification code of a firm can disappear for the following reasons: natural exit; ownership change (e.g., due to privatization or merger and acquisition) or industry switch; and decline of firm size to below the threshold when firms become reclassified as small firms and are excluded from the LME survey.

The existence of different causes for a firm to disappear from the data may blur the firm survival analysis. However, our main reason for analyzing survival is to correct for a possible bias in the job-creation analysis. The difference in reasons causing firms to disappear from the data is presumably of minor importance for this issue.

Finally, the coverage of LMEs was enlarged in the 2004 Economic Census of China, as compared to surveys in previous years. Furthermore, in the 2004 census, S&T statistics were reported at the firm level. Previous surveys reported S&T at the level of enterprise groups and all firms belonging to a group were added together and recorded as one observation. As a result, observations of the total number of firms and the number of firms with S&T both increased in 2004.

4.4 Descriptive statistics

Table 1 shows the numbers of firms and employees between 1998 and 2004 by S&T status in Chinese industrial firms. The number of firms has increased over the period, from 23,105 in 1998 to 27,712 in 2004, and the main part of the increase is in the second period when the number of firms increased by almost 24 percent.[10] It is interesting to note that growth has been comparably high in the number of firms without S&T. For instance, the total number of firms without S&T increased by about 4 percent during the first period, as compared to a decline of about 10 percent for firms with S&T. The development in the second period is even more striking with a large increase in firms without S&T (40.3 percent) and a small increase in the number of firms with S&T (4.2 percent).[11]

The development of employment shows a pattern similar to growth in firms: employment declined by almost 20 percent between 1998 and 2001 with a relatively large decline for firms with S&T. Furthermore, employment increased by about 29 percent between 2001 and 2004, once more with a substantial growth in employment in firms without S&T (84 percent) and a small growth in employment in firms with S&T (4 percent).

The relatively large increase in employment in firms without S&T should not come as a surprise at the aggregate level because China has a comparative advantage in labor-intensive sectors but not in technology-intensive sectors. What we want to examine is if in a given sector, firms with S&T have grown more or less than firms without S&T. Looking at different sectors, it is particularly interesting to note that even in high-tech industries, firms and employment have increased substantially but with most of the increase taking place in firms without S&T. This might suggest that most activities in high-tech industries are of relatively low skill-intensity.

Table 1 also includes the five largest industries (in terms of value-added) at the two-digit level in 1998. Industry-level figures reveal the same story, where employment and the number of firms without S&T tend to increase more (decrease less) than the corresponding changes in firms with S&T. The sectors in Table 1 are rather broad. It is, of course, possible that firms with and without S&T are located in different subsectors, explaining the differences in growth in employment. To control for this possibility, we calculated employment growth at a four-digit level, which is the most disaggregated level available. Employment growth tends, again, to be highest in firms without S&T but the difference is less significant than the previous figures, es-

10 Once more, some of the increase between 2001 and 2004 is, according to officials at the National Bureau of Statistics, caused by an improved coverage of the census and not only by an increase in the real number of firms.

11 Here, once more, some of the changes might be due to the construction of the data rather than being real changes. All firms that belonged to large enterprise groups with S&T were reporting positive S&T before 2004. In the 2004 census, S&T were reported at the level of the firm and not at the level of the enterprise group.

Table 1. Number of firms and employment by S&T status in the Chinese industry

		1998		2001		1998–2001		2004		2001–2004	
		No. of firms	Employment	No. of firms	Employment	Growth in firms (%)	Growth in employment (%)	No. of firms	Employment	Growth in firms (%)	Growth in employment (%)
All firms	All	23,105	33,799,488	22,375	27,221,616	−3.2	−19.5	27,712	35,121,937	23.9	29.0
	ST=0	11,720	9,800,935	12,174	8,530,922	3.9	−13.0	17,084	15,674,462	40.3	83.7
	ST>0	11,385	23,998,553	10,201	18,690,694	−10.4	−22.1	10,628	19,447,475	4.2	4.0
High-technology industries	All	2,052	2,386,270	2,385	2,360,284	16.2	−1.1	3,119	3,887,558	30.8	64.7
	ST=0	570	343,688	849	504,529	48.9	46.8	1,417	1,552,194	66.9	207.7
	ST>0	1,482	2,042,582	1,536	1,855,755	3.6	−9.1	1,702	2,335,364	10.8	25.8
Ferrous metals	All	430	2,311,463	388	1,897,992	−9.8	−17.9	928	2,139,947	139.2	12.7
	ST=0	223	294,960	209	201,154	−6.3	−31.8	672	612,572	221.5	204.5
	ST>0	207	2,016,503	179	1,696,838	−13.5	−15.9	256	1,527,375	43.0	−10.0
Transport equipment	All	1,268	2,354,424	1,354	2,026,648	6.8	−13.9	1,668	2,216,519	23.2	9.4
	ST=0	438	396,496	535	390,528	22.1	−1.5	699	592,130	30.7	51.6
	ST>0	830	1,957,928	819	1,636,120	−1.3	−16.4	969	1,624,389	18.3	−0.7
Basic chemicals	All	1,845	2,365,526	1,757	1,829,700	−4.8	−22.7	1,664	1,742,936	−5.3	−4.7
	ST=0	850	649,129	874	556,388	2.8	−14.3	819	600,111	−6.3	7.9
	ST>0	995	1,716,397	883	1,273,312	−11.3	−25.8	845	1,142,825	−4.3	−10.2
Textiles	All	2,294	3,336,139	1,751	2,338,522	−23.7	−29.9	2,450	2,807,521	39.9	20.1
	ST=0	1,448	1,647,319	1,094	1,052,759	−24.4	−36.1	1,799	1,737,940	64.4	65.1
	ST>0	846	1,688,820	657	1,285,763	−22.3	−23.9	651	1,069,581	−0.9	−16.8
Petroleum products	All	155	619,659	164	428,594	5.8	−30.8	367	525,990	123.8	22.7
	ST=0	54	67,134	61	99,385	13.0	48.0	254	197,753	316.4	99.0
	ST>0	101	552,525	103	329,209	2.0	−40.4	113	328,237	9.7	−0.3

Source: *Data provided by the National Bureau of Statistics of China.*

Note: *Sectors have been chosen based on their size (value-added) in 1998.*

pecially in the second period. More specifically, employment growth was higher in firms without S&T than in firms with S&T in 100 of the 141 available sectors in the first period, and in 75 sectors in the second period (not shown).

Table 1 suggests that employment has increased more in firms without S&T than in firms with S&T, but the causality between S&T and growth in employment is unclear. An alternative approach to the issue of S&T and employment is to compare employment growth within firms with and without S&T. This is done in Table 2 where, for instance, we compare growth in employment between 1998 and 2001 in firms that conducted S&T and firms that did not conduct S&T in 1998. Hence, unlike Table 1, the sample only includes those firms that are present over the period 1998–2001 and/or 2001–2004.

Table 2 shows that employment has declined in the firms included; the number of employees decreased by about 17.3 percent between 1998 and 2001 and by about 3.2 percent between 2001 and 2004. The performance was similar in firms with and without S&T in the first period, but growth in employment has been positive in firms without S&T and negative in firms with S&T in the second period.

It is worth noting that firms in high-tech industries have seen a lower than average decline in employment in the first period and a positive employment growth in the second period. This could be an indication of an increased importance of high technology in the Chinese economy. However, it should also be emphasized that, even within high-tech industries, employment growth has been substantially higher in firms without S&T.

The pattern of a comparably strong employment growth in firms without S&T is also seen in other sectors: employment growth is higher in firms with S&T than in firms without S&T in only one industry in 1998–2001 (ferrous metals) and one industry in 2001–2004 (petroleum products). Hence, there does not seem to be any positive effect of S&T on employment growth, given the descriptive figures in Table 2.

As previously discussed, employment has declined rapidly in Chinese SOEs. This is likely to be one cause for the negative growth in employment seen in Table 3. It is also possible that the development in SOEs shades the role of S&T in employment. Therefore, we divide our sample of firms by ownership in Table 3.

Table 3 shows that, not surprisingly, the number of employees has declined rapidly in SOEs: around 20 percent between 1998 and 2001, and 12 percent between 2001

Table 2. Employment by S&T, sector, and year

		Firms existing both 1998 and 2001				Firms existing both 2001 and 2004			
		No. of firms In both 1998, 2001	Employment In 1998	Employment In 2001	Growth in employment 1998–2001 (%)	No. of firms In both 2001, 2004	Employment In 2001	Employment In 2004	Growth in employment 2001–2004 (%)
All	All	13,678	23,133,225	19,125,606	−17.3	8,887	16,849,019	16,307,942	−3.2
	ST=0	6,129	5,674,079	4,778,958	−15.8	3,712	4,173,138	4,620,203	10.7
	ST>0	7,549	17,459,146	14,346,648	−17.8	5,175	12,675,881	11,687,739	−7.8
High tech	All	1,398	1,830,782	1,610,291	−12.0	1,137	1,621,924	1,735,332	7.0
	ST=0	334	232,507	240,614	3.5	313	322,211	445,845	38.4
	ST>0	1,064	1,598,275	1,369,677	−14.3	824	1,299,713	1,289,487	−0.8
Ferrous metals	All	233	1,644,892	1,403,571	−14.7	181	1,407,765	1,256,062	−10.8
	ST=0	96	144,796	109,495	−24.4	65	81,695	96,638	18.3
	ST>0	137	1,500,096	1,294,076	−13.7	116	1,326,070	1,159,424	−12.6
Transport equipment	All	878	1,933,898	1,607,284	−16.9	673	1,404,925	1,217,057	−13.4
	ST=0	256	265,445	209,951	−20.9	188	193,034	209,976	8.8
	ST>0	622	1,668,453	1,397,333	−16.2	485	1,211,891	1,007,081	−16.9
Basic chemicals	All	1,118	1,604,819	1,264,529	−21.2	671	1,105,020	923,387	−16.4
	ST=0	458	382,151	308,689	−19.2	225	240,614	212,657	−11.6
	ST>0	660	1,222,668	955,840	−21.8	446	864,406	710,730	−17.8
Textiles	All	1,069	1,743,761	1,448,006	−17.0	634	1,234,471	1,215,872	−1.5
	ST=0	612	749,077	623,982	−16.7	311	450,797	494,086	9.6
	ST>0	457	994,684	824,024	−17.2	323	783,674	721,786	−7.9
Petroleum products	All	100	447,400	258,035	−42.3	101	360,873	276,645	−23.3
	ST=0	28	34,596	33,254	−3.9	25	64,413	44,319	−31.2
	ST>0	72	412,804	224,781	−45.5	76	296,460	232,326	−21.6

Source: *Data provided by the National Bureau of Statistics of China.*

Table 3. Average employment by S&T, ownership, and year

		Firms existing both 1998 and 2001				Firms existing both 2001 and 2004			
		No. of firms In both 1998, 2001	Employment In 1998	Employment In 2001	Growth in employment 1998–2001 (%)	No. of firms In both 2001, 2004	Employment In 2001	Employment In 2004	Growth in employment 2001–2004 (%)
SOE	All	7,648	17,273,347	13,802,597	−20.1	3,208	9,155,995	8,059,018	−12.0
	ST=0	3,052	3,489,127	2,748,998	−21.2	1,119	1,544,624	1,627,300	5.4
	ST>0	4,596	13,784,220	11,053,599	−19.8	2,089	7,611,371	6,431,718	−15.5
Collective	All	1,939	1,634,270	1,447,056	−11.5	642	800,984	781,872	−2.4
	ST=0	983	690,123	585,250	−15.2	305	331,413	315,907	−4.7
	ST>0	956	944,147	861,806	−8.7	337	469,571	465,965	−0.8
Joint vent. Hong Kong; Taiwan; Macau	All	930	768,106	726,242	−5.5	937	1,033,738	1,292,986	25.1
	ST=0	563	349,164	365,839	4.8	525	548,024	710,238	29.6
	ST>0	367	418,942	360,403	−14.0	412	485,714	582,748	20.0
Joint vent.	All	1,029	722,546	718,375	−0.6	834	809,247	951,667	17.6
	ST=0	593	299,951	336,539	12.2	413	339,773	431,246	26.9
	ST>0	436	422,595	381,836	−9.6	421	469,474	520,421	10.9
Foreign	All	235	152,326	186,421	22.4	420	481,289	665,780	38.3
	ST=0	227	147,403	181,917	23.4	325	353,860	498,028	40.7
	ST>0	8	4,923	4,504	−8.5	95	127,429	167,752	31.6
Shareholding	All	1,711	2,430,047	2,118,891	−12.8	2,471	4,272,350	4,206,673	−1.5
	ST=0	619	636,972	508,839	−20.1	830	922,346	871,169	−5.5
	ST>0	1,092	1,793,075	1,610,052	−10.2	1,641	3,350,004	3,335,504	−0.4
Private	All	78	51,159	49,241	−3.7	338	267,536	326,439	22.0
	ST=0	49	29,323	28,128	−4.1	183	127,614	159,723	25.2
	ST>0	29	21,836	21,113	−3.3	155	139,922	166,716	19.1
Other	All	108	101,424	76,783	−24.3	37	27,880	23,507	−15.7
	ST=0	43	32,016	23,448	−26.8	12	5,484	6,592	20.2
	ST>0	65	69,408	53,335	−23.2	25	22,396	16,915	−24.5

Source: *Data provided by the National Bureau of Statistics of China.*

and 2004. Employment has also declined in both periods in collective, shareholding, and other domestic firms. The result for private domestic firms is mixed with a small decline in the first period (−3.7 percent) and with an increase in the second period (22 percent).

Firms with foreign ownership are divided in three groups: joint ventures with firms from Hong Kong, Macau, and Taiwan; joint ventures with firms from other countries; and wholly foreign-owned firms. Joint ventures with greater China have had a growth in employment in both periods, whereas the other type of joint ventures had a stagnant job growth in the first period and a positive job growth in the second period. Wholly foreign-owned firms have shown the highest growth in employment, about 22 percent in the first period and about 38 percent in the second period.

Returning to the relationship between S&T and job growth, our previously expressed suspicion that a negative relation is caused by the development in SOEs is only partly supported by the data. Job growth has been poorer in SOEs with S&T than in SOEs without S&T. However, the same development is also found in all three groups with foreign ownership where employment has grown faster in firms without S&T. In fact, all types of foreign firms with S&T had a negative employment growth in the first period.

Firms with S&T have a higher employment growth than firms without S&T in two ownership groups, collectives and shareholdings, whereas the results for private firms are inconclusive with a seemingly positive effect in the first period, but a negative effect in the second period.

These results show that S&T does not have a positive impact on employment. If anything, the results suggest that firms without S&T have increased their employment faster.

Survival is another mechanism through which S&T might affect employment. In other words, there might be a positive relation between S&T and the survival of firms, something that is overlooked in Tables 3 and 4 where, obviously, only surviving firms are included. Table 4 includes figures on how large a proportion of all firms that were present in, for instance, 1998, survived until 2001. The survival rate is divided among firms with and without S&T. The figures show that roughly 59 percent of all firms that existed in 1998 survived until 2001. The survival rate decreases substantially in the second period, where it amounts to about 40 percent.

Table 4. Survival by S&T, sector, and year (%)

		No. of firms in 1998	Remained in 2001	%	No. of firms in 2001	Remained in 2004	%
All firms	All	23,105	13,678	59.2	22,375	8,887	39.7
	ST=0	11,720	6,129	52.3	12,174	3,712	30.5
	ST>0	11,385	7,549	66.3	10,201	5,175	50.7
High tech	All	2,052	1,398	68.1	2,385	1,137	47.7
	ST=0	570	334	58.6	849	313	36.9
	ST>0	1,482	1,064	71.8	1,536	824	53.6
Ferrous metals	All	430	233	54.2	388	181	46.6
	ST=0	223	96	43.0	209	65	31.1
	ST>0	207	137	66.2	179	116	64.8
Transport equipment	All	1,268	878	69.2	1,354	673	49.7
	ST=0	438	256	58.4	535	188	35.1
	ST>0	830	622	74.9	819	485	59.2
Basic chemicals	All	1,845	1,118	60.6	1,757	671	38.2
	ST=0	850	458	53.9	874	225	25.7
	ST>0	995	660	66.3	883	446	50.5
Textiles	All	2,294	1,069	46.6	1,751	634	36.2
	ST=0	1,448	612	42.3	1,094	311	28.4
	ST>0	846	457	54.0	657	323	49.2
Petroleum products	All	155	100	64.5	164	101	61.6
	ST=0	54	28	51.9	61	25	41.0
	ST>0	101	72	71.3	103	76	73.8

Source: *Data provided by the National Bureau of Statistics of China.*

The exit rate in the first period is broadly in line with the results for other countries.[12] The second period, however, shows an exit rate that is considerably higher than what is typically the case in other countries. Once more, our exit rate can be caused by other factors than the "death" of a firm and is therefore not directly comparable with figures from other studies.

The survival rate differs between industries and seems to be particularly high in petroleum and low in textiles. More importantly, there seems to be a positive relation between S&T and survival: firms with S&T are comparably likely to survive in all industries and in both periods. One plausible reason is that investment in S&T is typically a long-term decision that should be appealing only to those firms who expect to remain in business over some time.

To sum up the results, the simple tabulations in the tables seem to suggest that, first, S&T have no positive effect on job-creation, and second, S&T have a positive effect on firm survival. Hence, although the figures suggest that S&T do not create jobs, they seem to maintain jobs by affecting the survival rate.

12 See, for example, Roberts and Tybout (1996) and Bernard and Sjöholm (2003).

Table 5. Firm characteristics by S&T and year (firm average 1,000 yuan)

		1998	2001	2004
Average employment per firm	ST=0	836	701	917
	ST>0	2,108	1,832	1,830
Export as a share of sales (%)	ST=0	20.3	22.0	31.1
	ST>0	9.7	12.3	17.0
Import of technology as a share of sales (%)	ST=0	0.2	0.1	0.1
	ST>0	0.7	0.6	0.4
Profits as a share of sales (%)	ST=0	0.0	3.9	5.4
	ST>0	3.2	6.8	7.9
Average wage per employee	ST=0	6.9	10.2	14.3
	ST>0	8.9	12.8	20.3
Value-added per employee	ST=0	93.9	176.2	288.8
	ST>0	112.7	211.6	438.8
Fixed assets (capital) per employee	ST=0	92.1	140.5	125.4
	ST>0	93.0	148.6	201.0

Source: *Data provided by the National Bureau of Statistics of China.*

The main constraint of this analysis is obvious: job growth and firm survival are affected by a host of factors other than those included in the tables. If such characteristics differ between firms with and without S&T, there is a risk that our comparison is biased. Indeed, Table 5 shows there to be large differences between firms with and without S&T in all sectors and in all periods. More specifically, firms with S&T tend to be relatively large, capital-intensive firms with high profits, productivity, and wages, and with a large amount of imports of technologies. Firms with no S&T tend to have a substantially higher share of exports.

Controlling for various factors that affect employment and allowing all Chinese firms to be included in the data require an econometric approach that we now employ.

5. Econometric model and results

5.1 Model

We use a Heckman two-step estimator to control for the sample selection problem caused by attrition (firms dropping out from the data set) (Puhani 2000). The Heckman approach controls for the effect of firm survival before we estimate the impact of S&T on employment. In the first step, we estimate a probit model for firm exit as specified in equation (1). We experiment with using different sets of controls, ranging from an S&T status dummy only, to the most comprehensive model, which includes S&T intensity, ownership, skill- and capital-intensities, and a set of dummy variables to control for export- and import-status, as well as for year- and industry-specific effects. We use the most comprehensive model to calculate the inverse Mills ratio.

$$\hat{P}(Exit_{it}) = \Phi(Z_{i,t-1})$$
$$Z_{i,t-1} = \alpha + \beta_{st}\text{S\&T\_share}_{i,t-1} + \lambda_1\text{Firmsize}_{i,t-1} + \lambda_2\text{Skill\_Share}_{i,t-1} + \lambda_3\text{Capital\_intensity}_{i,t-1} + \Sigma\beta_w\text{Ownership}_i + \beta_{ex}\text{Export\_dummy}_{i,t-1} + \beta_{im}\text{Import\_dummy}_{i,t-1} + \Sigma\beta_t\text{Year\_dummy} + \Sigma\beta_{ind}\text{Ind\_dummy}_j \quad (1)$$

In the second step, the inverse Mills ratio is added to the model of employment growth as an explanatory variable. The employment growth model is specified as:[13]

$$\Delta X_{i,t} = InX_{it} - InX_{it-1} = \alpha + \Sigma\beta_n\text{S\&T\_share}_{i,t-n} + \lambda\text{Firm}_{i,t-1} + \Sigma\beta_w\text{Ownership}_i + \Sigma\beta_t\text{Year\_dummy} + \Sigma\beta_{ind}\text{Ind\_dummy}_j + \Sigma\beta_R\text{Reg\_dummy} + \gamma\text{Mills}_{it} + \epsilon_{it}, \quad (2)$$

where i is the index for firms, j is the index for industries, and t is the index for year. The model is estimated by applying OLS and fixed effect estimators on the full data set as well as on sub-samples by ownership and by industry sector. The variables included in the specification are defined as:

X_{it} = Employment

$S\&T\_share_{i,t-n}$ = The ratio of S&T expenditures to sales, where n is the number of lags.

$Firm_{i,t-1}$ = A vector of lagged firm characteristics such as size, labor productivity, skill intensity, export- and import-shares.

$Ownership_i$ = Ownership dummy variables= SOE, collective, joint venture with firms from Taiwan, Hong Kong, and Macau, joint venture with firms from other foreign countries, wholly foreign-owned, and private domestic firms.

$Year_t$ = Year dummy variable.

$Industry_j$ = Industry dummy variables at the four-digit level.

Reg_dummy = Regional dummy variables at the province level.

$Mills_{it}$ = The inverse of Mills ratio from the probit model estimation in Step 1, calculated as= $\frac{\phi(Z_{it})}{1-\Phi(Z_{it})}$, where ϕ is the standard normal probability density function and Φ is the standard normal cumulative density function.

13 See Table A2 in the Appendix for detailed definitions of the control variables at the firm- and industry-level.

Firm characteristics such as size and labor productivity are expressed in log forms. We try to avoid an endogeneity problem by using lagged values on S&T and other independent variables in our estimations. However, we will also use a matching approach, both as a robustness check and as an alternative attempt to control for the possibility that S&T is a function of, for instance, job growth.

The main advantage of the matching method is the ability to control for endogeneity. The idea behind the propensity score-matching estimator is that for every firm that performs S&T, we identify an "identical" firm that does not perform any S&T. We then compare job growth in the treated group (performs S&T) and the control group (does not perform S&T).[14] The treatment is defined by the S&T dummy variable ($S\&T\_dummy_{i,t-1}$), namely, whether firm i performs S&T activities or not at time $t-1$, and employment growth (ΔX_i) is the outcome variable. We use a set of lagged firm characteristics ($Firm_{i,t-1}$), such as firm size, labor productivity, export-share, import-share, capital-intensity, and industry affiliation at the two-digit level ($Industry_j$) to identify similar firms and perform the matching of treated and control firms. The propensity score is estimated as:

$$p(Firm_{i,t-1}, Industry_j) = \Pr\{S\&T\_dummy_{i,t-1} = 1 \mid Firm_{i,t-1}, Industry_j\} \quad (3)$$

Finally, the average treatment effect on the treated (ATT) is estimated as:

$$ATT = E\{E\{\Delta X_{1i} - \Delta X_{0i} \mid S\&T\_dummy_{i,t-1} = 1, p(Firm_{i,t-1}, Industry_j)\}\}. \quad (4)$$

5.2 Results

Table 6 shows probit estimations on firms' likelihood to exit from the market and how this likelihood is affected by firm characteristics. A negative coefficient means that the likelihood of exit decreases. In addition to controlling for sample selection bias, we can also make use of this estimation to identify the factors that affect firm exit. As previously discussed, the data are constructed in such a way that we cannot distinguish death of firms from two other forms of exit: a change in ownership or a decline in size to below the threshold. Bearing this caveat in mind, we notice in the first column that S&T has a positive and statistically significant impact on survival: firms with any S&T are significantly less likely to exit compared to firms without S&T.

In the previous sections, we have seen that firms with and without S&T differ in a number of aspects, which could also affect the exit rate. We try to control for such

14 We apply the nearest neighbor matching with replacement; see Becker and Ichino (2002) for more details.

Table 6. Firm exit (probit estimations; dependent variable: exit = 1, survival = 0)

	(1)	(2)	(3)	(4)	(5)	(6)
S&T dummy	−0.338** (0.008)	−0.228** (0.009)	−0.211** (0.009)			
S&T intensity				−0.001 (0.002)	−0.018** (0.005)	−0.014** (0.007)
Size		−0.254** (0.003)	−0.247** (0.003)		−0.273** (0.003)	−0.259** (0.003)
Ownership SOE		−0.224** (0.040)	−0.220** (0.040)		−0.266** (0.040)	−0.255** (0.040)
Ownership collective		−0.083* (0.040)	−0.079* (0.040)		−0.078* (0.040)	−0.074* (0.040)
Ownership JV_KTM		−0.318** (0.041)	−0.291** (0.041)		−0.295** (0.041)	−0.269** (0.041)
Ownership JV_Foreign		−0.330** (0.042)	−0.304** (0.042)		−0.319** (0.042)	−0.290** (0.042)
Ownership foreign		−0.529** (0.044)	−0.489** (0.045)		−0.478** (0.045)	−0.442** (0.045)
Ownership shareholding		−0.248** (0.040)	−0.240** (0.040)		−0.275** (0.040)	−0.261** (0.040)
Ownership private		−0.221** (0.042)	−0.219** (0.042)		−0.207** (0.042)	−0.208** (0.042)
Skill share			−0.011 (0.009)			−0.028* (0.015)
Capital intensity			−0.0001** (0.00004)			−0.0001** (0.0004)
Export dummy			−0.103** (0.010)			−0.119** (0.009)
Import dummy			−0.045** (0.017)			−0.155** (0.016)
Year dummy	Yes	Yes	Yes	Yes	Yes	Yes
Industry dummy (4-digit)	Yes	Yes	Yes	Yes	Yes	Yes
No. of obs.	170,489	165,964	165,796	165,964	165,964	165,796

Source: *Data provided by the National Bureau of Statistics of China.*

Note: *Robust standard errors are within parentheses. *Statistically significant at the 5 percent level. ** Statistically significant at the 1 percent level.*

JV_KTM = joint ventures with firms from Hong Kong, Taiwan, and Macau; JV_Foreign = joint ventures with foreign firms outside of Hong Kong, Taiwan, and Macau.

characteristics in the following estimations. Column (2) shows that large firms are substantially less likely to exit. Moreover, all the included ownership variables are statistically significant with negative signs showing that firms with any of these ownerships are less likely to exit than the group of comparison: other domestic firms.[15] We can also see that the coefficients differ between ownership groups with a large negative coefficient for foreign ownership and a smaller negative coefficient for collective ownership. The inclusion of additional variables decreases the effect of

15 The group other domestic firms consists of state-collective jointly operated enterprises, other jointly operated enterprises, limited liability enterprises, and shareholding limited enterprises.

S&T on survival in column (1); thereby suggesting that some of the previously estimated effect is caused by differences in other characteristics than S&T.

We include a number of new variables in column (3). The results show that firms integrated with the global economy in terms of export or import of technology are relatively less likely to exit. Moreover, a high skill-share or high capital-intensity has no, or a very limited, impact on survival and the inclusion of these two additional control variables does not affect the other coefficients.

The previous estimations show that firms with any S&T are less likely to exit than firms without S&T. In columns (4)–(6), we continue to examine if the amount of S&T affects exit by examining the effect of S&T intensities on firm survival. The results suggest that the higher the S&T intensity, the less likely is the firm to exit. The other coefficients are similar to previous estimations.[16]

Next, we turn to our question of main interest: how S&T affects job growth. We approach the issue by estimating regressions in Table 7 with growth in employment as the dependent variable and with various independent variables, including the S&T intensity, which potentially affects job growth. As previously stated, it is important to control for the possible bias caused by a sample where we only observe growth in employment in surviving firms. The need to control for this aspect seems particularly high in view of the positive effect of S&T on job survival found in Table 6. We therefore calculate the Mills ratio from column (6) in Table 6 and then include it in the job-growth regressions.

The time it takes for S&T to affect job growth is uncertain. We therefore start in column (1) by including five lags of S&T. The results show that only lag 1 is statistically significant with a positive sign. One disadvantage with the inclusion of many lags is that it substantially reduces the sample. This is seen in column (2) where the sample increases from 16,834 observations (column (1)) to 130,150 observations when only one lag is included. The change of sample size presumably explains the change in the result for S&T, which is not found to affect job growth in estimation 2. We see that large firms have a relatively low job-growth when looking at the other variables in the OLS estimations in columns (1) and (2). Moreover, there is a positive impact on job growth of productivity, skills, export, and import of technology. Job growth also differs between different ownership types.

16 We did also try with the more narrow measure on technology development, R&D. The results did not change in any major respect.

Table 7. Employment growth regression (dependent variable: employment growth)

	Without Mills ratio			With Mills ratio		
	(1) OLS	(2) OLS	(3) FE	(4) OLS	(5) OLS	(6) FE
S&T share (lagged −1)	0.022 (0.002)**	0.002 (0.002)	0.001** (0.000)	0.022 (0.002)**	0.002 (0.002)	0.001** (0.000)
S&T share (lagged −2)	0.020 (0.058)			0.017 (0.058)		
S&T share (lagged −3)	−0.042 (0.048)			−0.041 (0.048)		
S&T share (lagged −4)	0.036 (0.038)			0.035 (0.037)		
S&T share (lagged −5)	−0.044 (0.029)			−0.044 (0.029)		
Year dum	Yes	Yes	Yes	Yes	Yes	Yes
Industry dum	Yes	Yes	—	Yes	Yes	—
Regional dum	Yes	Yes	—	Yes	Yes	—
Lagged firm size	−0.055** (0.004)	−0.041** (0.002)	−0.397** (0.004)	−0.062** (0.007)	−0.049** (0.004)	−0.405** (0.004)
Lagged labor productivity	0.118** (0.006)	0.127** (0.003)	0.530** (0.003)	0.119** (0.006)	0.127** (0.003)	0.530** (0.003)
Ownership SOE	0.011 (0.026)	0.026* (0.012)		0.005 (0.026)	0.019 (0.012)	
Ownership collective	0.002 (0.027)	0.020 (0.012)		0.002 (0.027)	0.019 (0.012)	
Ownership JV_KTM	0.044 (0.026)	0.041** (0.012)		0.038 (0.027)	0.034* (0.013)	
Ownership JV_Foreign	0.035 (0.026)	0.009 (0.012)		0.029 (0.027)	0.002 (0.012)	
Ownership foreign	0.076** (0.027)	0.058** (0.013)		0.068** (0.028)	0.048** (0.014)	
Ownership shareholding	0.015 (0.026)	0.033** (0.012)		0.010 (0.026)	0.027* (0.012)	
Ownership private	0.021 (0.027)	0.058** (0.013)		0.017 (0.027)	0.053** (0.013)	
Lagged skill share	0.090* (0.040)	0.026** (0.005)	0.032** (0.001)	0.087* (0.040)	0.026** (0.005)	0.032** (0.001)
Lagged export share	0.033** (0.011)	0.060** (0.004)	−0.006 (0.010)	0.031** (0.011)	0.057** (0.004)	−0.009 (0.010)
Lagged imp. share	0.206** (0.073)	0.020** (0.008)	0.052* (0.025)	0.189** (0.074)	0.020** (0.008)	0.047* (0.025)
Mills ratio				−0.054 (0.045)	−0.082* (0.030)	−0.078** (0.024)
No. of obs.	16,834	130,150	130,150	16,818	130,085	130,085
R^2	0.15	0.10	—	0.15	0.10	—

Source: *Data provided by the National Bureau of Statistics of China.*

Note: *Robust standard errors are within parentheses. *Statistically significant at the 5 percent level. ** Statistically significant at the 1 percent level.*

JV_KTM = joint ventures with firms from Hong Kong, Taiwan, and Macau; JV_Foreign = joint ventures with foreign firms outside of Hong Kong, Taiwan, and Macau.

The fixed effect estimation in column (3) shows that the increase in S&T intensity has a positive and statistically significant effect on job creation. However, the coefficient is small, suggesting that the economic significance is negligible. The effect of size, productivity, skill, and technology import is similar to previous estimations but there is less evidence of exports having an effect on job-growth. When random effects models are used, the data fail the Hausman specification test. Thus, they are excluded from the table.

We control for a possible selection bias by including the Mills ratio in columns (4)–(6) in Table 7. The Mills ratio is statistically significant, which shows that its inclusion is warranted. However, the other results remain stable with a positive effect on job-growth mainly from productivity, skills, and technology import and a negative effect of size. Hence, small firms with a skilled labor force and high labor productivity tend to grow relatively fast. There is no clear-cut evidence of an effect of S&T on job growth.

As in the previous estimation on survival, we tried different measures on technology, such as dummy variables for S&T and R&D, and R&D intensity, but the results were not affected largely by these different specifications. We also examined job growth in groups of firms with different types of ownerships. The results are shown in Table 8. S&T has a positive and statistically significant effect on job growth among SOEs. One reason could be if SOEs are guided by objectives other than profit-maximization, and if employment in these firms might be determined differently than in firms with other types of ownership. Still, the coefficient is small, indicating that the positive effect is of little economic significance.

There is no effect of S&T on job growth in private Chinese firms or in joint ventures with firms from Hong Kong SAR, Taiwan, and Macau SAR (HKTM). Moreover, S&T has a negative impact on job growth in other types of foreign-owned firms. The negative economic effect is quite large with an increase of 1 percent in the S&T intensity leading to a 0.24 percent decline in employment.

Furthermore, we divide the sample into high-tech industries and other industries. The effect of S&T is positive and statistically significant in non-high-tech industries, but with small economic significance.

Finally, we experiment with different specifications of propensity score estimations in Table 9, ranging from firm characteristics only, to expanding the model with ownership dummy variables and industry affiliation dummy variables. Even though the magnitudes of ATTs vary with different specifications, the signs of ATTs are consis-

Table 8. Employment growth regression by ownership (fixed effect estimations)

	(1) SOE+ collective	(2) Private	(3) JV_HKTM	(4) Foreign + JV_Foreign	(5) High tech	(6) Other industries
S&T share (lagged −1)	0.001** (0.000)	−0.104 (0.133)	−0.076 (0.075)	−0.239** (0.072)	0.000 (0.000)	0.024** (0.001)
Year dummy	Yes	Yes	Yes	Yes	Yes	Yes
Lagged firm size	−0.417** (0.006)	−0.501** (0.017)	−0.444** (0.010)	−0.401 (0.008)	−0.380** (0.010)	−0.394** (0.004)
Lagged labor productivity	0.544** (0.005)	0.633** (0.017)	0.583** (0.010)	0.493** (0.009)	0.478** (0.010)	0.536** (0.004)
Lagged skill share	0.028** (0.001)	0.014 (0.096)	0.193** (0.058)	0.228** (0.041)	0.159** (0.030)	0.031** (0.001)
Lagged export share	0.036 (0.025)	0.025 (0.043)	−0.020 (0.018)	−0.035** (0.016)	−0.053* (0.025)	0.002 (0.011)
Lagged import share	0.010* (0.052)	0.210 (0.243)	0.023 (0.122)	0.013 (0.032)	0.031 (0.080)	0.050* (0.026)
Year dummy	Yes	Yes	Yes	Yes	Yes	Yes
No. of obs.	60,166	8,078	15,438	16,149	13,334	116,816

Source: *Data provided by the National Bureau of Statistics of China.*

Note: *Robust standard errors are within parentheses. *Statistically significant at the 5 percent level. ** Statistically significant at the 1 percent level. The Mills ratio is included in the model as a robustness check and yields similar results.*

JV_HKTM = joint ventures with firms from Hong Kong, Taiwan, and Macau; JV_Foreign = joint ventures with foreign firms outside of Hong Kong, Taiwan, and Macau.

Table 9. Difference in annual average employment growth between S&T-performing and non-S&T-performing firms by matching (outcome variable: annual employment growth)

Specification of propensity score estimation	Treated	Controls	ATT/ Difference
(1) *Unmatched*	−0.050	−0.018	−0.032** (0.002)
(2) Firm characteristics only	−0.050	−0.047	−0.003 (0.003)
(3) Firm characteristics + Ownership dummy	−0.050	−0.039	−0.010* (0.003)
(4) Firm characteristics + Ownership dummy + Industry affiliation	−0.050	−0.046	−0.004 (0.004)
No. of obs.	51,643	78,507	

Source: *Data provided by the National Bureau of Statistics of China.*

Note: *Standard errors are within parentheses. * Statistically significant at the 5 percent level; **Statistically significant at the 1 percent level.*

tently negative, but not always significant. Hence, employment decreases at a higher rate in firms with S&T activity (treatment) than in firms without S&T activity, as shown in estimation (3) or, at best, there is no difference in employment growth, as shown in estimations (2) and (4).

Hence, these results show no signs of a positive effect of S&T on growth in employment. However, there are two qualifications to discuss: whether there are externalities from S&T and whether the results differ for small firms.

Starting with externalities, if S&T has a positive effect on actors outside of the conducting firm, it could provide an argument for subsidizing S&T. Such externalities are often mentioned by politicians and policymakers but are difficult to measure. However, because we find no direct effect of S&T on employment—effect on the S&T conducting firm's employment—it seems unlikely that there would be positive effect on employment in other firms.

We can only make conclusions for our sample of medium- and large-sized Chinese firms. It is possible that S&T has a positive effect on employment in small firms, but we are unable to examine this issue because of data limitations. What we know is that small firms play a small role in Chinese S&T. For instance, Sjöholm and Lundin (2010) find that only 9 percent of small firms conduct any S&T in 2004, and that these small firms account for only 16.7 percent of total Chinese S&T. The low importance of small firms in Chinese S&T suggests that even if S&T would have a positive effect on employment in small firms, the effect on total Chinese employment is likely to be limited.

6. Concluding remarks

China is striving to upgrade its technological potential. Sharp increases in expenditures on S&T and large subsidies and tax rebates to firms that conduct S&T research have been implemented to transform China into an innovation-driven economy. Such policies to promote indigenous technology development are costly and, as witnessed in many other developing countries, often inefficient.

Can Chinese policymakers spend their resources more efficiently? The answer depends on what is identified to be China's main economic challenge. The growth of modern-sector employment is one of the most pressing economic issues: the pool of underemployed people is huge and Chinese industry does not absorb sufficiently large numbers of workers. Our analysis shows that S&T does not increase employment.

Hence, addressing the employment issue requires different policies than those focusing on technology development. It is beyond the scope of this study to suggest comprehensive and detailed policies for employment growth in China. However, it is clear from our analysis that small firms grow faster than large firms do, and policies directed toward these small firms are therefore likely to be positive. There are several areas where small private Chinese firms are disfavored, such as access to capital and foreign markets (Huang et al. 2004; Sjöholm and Lundin 2010).

Moreover, foreign firms in China create more new jobs than domestic firms do (Karlsson et al. 2009). It is therefore unfortunate from the point of employment creation, that policies toward FDI in China are becoming more restrictive, including higher demands on foreign firms to use high technology and to pursue technology development in China. Policies aiming at changing these conditions should be high on the Chinese government's priority list.

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Appendix

Table A1. Classification of large, medium, and small enterprises

	Large (1)	Medium (2)	Small (3)
Employment (person)	2,000+	300–2,000	300−
Turnover (million yuan)	300+	30–300	30−
Fixed assets (million yuan)	400+	40–400	40−

Source: *National Bureau of Statistics of China.*

Note: *Firms with a minimum turnover of 5 million yuan are included in the sample of the economic census of China. The classification of firm size is made according to the above combined indictors. Firms are classified as large if all three criteria in column (1) are satisfied. The remaining firms are classified as medium if all three lower bounds in column (2) are satisfied. Otherwise they are classified as small.*

Table A2. Definitions of variables

Variable	Definition
S&T intensity	S&T to total sales ratio
Firm size	Logarithm of real sales
Labor productivity	Logarithm of real value-added per employee
Profit share	Profit to total sales ratio
Skill intensity	Number of S&T personnel in the total number of employees
Capital intensity	Capital stock divided by the total number of employees
Technology import share	Expenditure of technology import to sales ratio
Technology import ratio	Technology to total sales ratio
Export share	Export to total sales ratio
Import share	Import to total sales ratio
Export dummy	Export dummy = 1 if export >0
Import dummy	Import dummy = 1 of technology import >0