Technology Adoption and Absorption: The Case of China

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Abstract

Using a unique firm-level survey dataset collected by one of the authors, this paper addresses two questions central to the literature on technology diffusion: What factors influence technology adoption, and how well do firms absorb 'new' technology? We find that firms with better access to cheap bank credit are more likely to adopt larger technology projects and invest more in imported equipment from technically-advanced countries. On the other hand, the return to technology investment differs significantly across firms. Firms with better access to cheap credit have significantly lower project profitability and capacity utilization. These results have important implications for the role of financial development in technology diffusion.

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1. Introduction

It is well recognized that technology diffusion is an essential component of technological progress and thus an important source of economic growth. Cross-country studies find strong evidence that investment in technology-embodied equipment is significantly correlated with economic growth for a wide range of countries (De Long and Summers 1991, Jones 1994, Eaton and Kortum 2001). On the other hand, micro-level studies point out various factors that affect technology diffusion, e.g., firm size, firm age, ownership types, market structure, and regulatory restriction (Dunne 1994, Rose and Joskow 1990, Levin, Levin, and Meisel, 1987, Hannan and McDowell 1984, Cohen and Levin 1989).

However, most micro-level studies have focused on technology diffusion in developed countries, especially the United States. Studies on developing countries at the firm level are scarce. One notable exception is Vishwasrao and Bosshardt (2001). Since developing countries have different institutions, technology, and endowments, we expect that the process of technology diffusion would differ from that for developed countries. Yet not much is known empirically about the factors affecting technology adoption by firms in the developing world and the subsequent impact on firm performance. Given the strong link between technology diffusion and economic growth, facilitating successful technology transfer is a central issue for developing countries.

This paper examines technology adoption and absorption in China using a unique firm-level survey dataset collected by one of the authors. This survey covers 250 randomly-selected firms in Shanghai, the home of some of China's most technologically advanced firms. The survey provides us detailed information on each firm's largest technology renovation project (*jishu kaifa xiangmu*) that was carried out between 1985 and 1992. These technology projects were for the express purpose of renovating or modernizing the production operations of a firm. On average investment in equipment and new production facilities constituted about 80 percent of the total project expenditure. In particular, expenditure on imported equipment captured nearly 30 percent of the project budget. The survey also has rich information on the firms and their market environment.

Our survey covers an important period of China's economic reform. China began a systematic effort to reform industrial enterprises in 1984. The government relaxed controls over most product prices through the introduction of the dual-track system (Naughton 1995, Lau, Qian, and Roland 2000). Firms that were largely controlled by the state were given new autonomy. The objectives of these firms were gradually shifted to emphasize increasing profits instead of fulfilling output quotas or other plan targets. However, economic reform in the financial sector lagged behind. Lending by China's state-owned banks was largely administratively determined through the national credit plan (Lardy 1998, Brandt and Zhu 2000). Nearly 90 percent of all lending by the state-owned banks went to the state-owned firms at real interest rates that were well below the opportunity cost of investment. In this paper we will present evidence that distortions in the financial market generate distortions in investment behavior of these state-owned firms and further affect their performance.

We first examine firm decisions about project size and investment in imported versus domestic equipment. Project size and investment in imported equipment are closely linked to technology advancement and competitive advantage in product markets. We find that state-owned firms with better access to bank loans adopt significantly larger projects and invest more in imported equipment. The estimates suggest that for state-owned firms, a

1 percentage point increase in the fraction of project expenditure that is financed through bank loans is associated with a 1.38 percent increase in project size and 2.13 percent increase in the expenditure on imported equipment. This result holds when we control for various factors that may also affect technology adoption e.g., firm profitability (a proxy for internal funds), firm size, firm age, human capital, physical capital intensity, sector and the year when the project began.

We then evaluate the performance of technology project using project profitability and capacity utilization rates. Project profitability is measured as a ratio of project gross profits to project size. We find that state-owned firms with better access to bank loans have lower project profitability and capacity utilization: a 1 percentage point increase in the share of project expenditure that is financed through bank loans is related to a 2.30 percent decrease in project profitability and a 0.26 percent decrease in capacity utilization rates. However, we do not find a significantly negative correlation between bank loans and project profitability or capacity utilization for other ownership types.

Therefore, although government support (mainly in the form of bank loans) can push state-owned firms to adopt more advanced technology, the government may be unable to solve easily the problem of technology absorption. In fact, pushing some state-owned enterprises to adopt more expensive and advanced technology can lower project performance given the weak capabilities of these firms.

These results have important implications for the role of financial development in technology diffusion. Only when resources are well allocated to match technology and firms can the economy reap fully the benefits from increasing investment in technology-embodied equipment. Otherwise, investment will only result in overcapacity with higher absorption costs and lower profitability. Our results also provide empirical support for the theoretical literature that emphasizes the role of financial development in economic growth (Gerschenkron 1962, Greenwood and Jovanovic 1990, Acemoglu, Aghion and Zilibotti 2002, Levine 1997, Rajan and Zingales 1998).

We also find that (1) firms with larger fixed assets and higher output prior to the project adopt bigger projects; (2) more profitable firms invest more in imported equipment while labor-intensive firms invest more in domestic equipment; (3) firms with higher physical capital intensity and profitability prior to the project have higher project profitability; and (4) project profitability and capacity utilization increase over the length of the project. These results suggest that technical capacity and learning by doing also play certain roles in technology diffusion. Thus, our results are also consistent with the studies that emphasize the importance of technical capacity in technology transfer, e.g., Evenson and Westphal (1995).

The paper is organized as follows. Section 2 describes the data, including an overview of the firms in our sample, their operations and market environment, and technology projects. Section 3 presents a simple theoretical model of firm investment decisions. Detailed empirical analysis is given in sections 4 and 5. Section 4 focuses on technology choices, i.e., project size, and investment in imported and domestic equipment. Section 5 analyzes project performance in terms of project profitability and capacity utilization. Section 6 draws the conclusions.

2. The Data

2.1. The Survey

The survey was carried out by the Shanghai branch of the National Statistical Bureau on our behalf in the fall of 1995 and spring of 1996. Altogether, 250 firms in Shanghai were randomly selected and surveyed in five sectors – chemical, machinery, transportation, electrical equipment and machinery, and electronic and telecommunication equipment industries. In 1993 these five sectors were the source of 40 percent of total industrial output in Shanghai, and 30 percent nationally. Survey forms were reviewed on two separate occasions and sent back to the firms for revision. After careful assessment, 2 firms were dropped from the sample because of unsatisfactory forms, leaving us with a total of 248 firms, 124 of which were state-owned enterprises, 74 collectively-owned enterprises, and 50 joint ventures.[1]

The survey itself was divided into four components. The first part provides basic information on the firm, including fixed assets, employment, profits, and output for 1987-93. The second part contains data on wages, labor composition by education, and other personnel information. The third part was filled out by either the general manager or factory manager of the firm and covers the firm's operations and market environment. The final part, which is the core of the survey, provides detailed information on each firm's largest technology renovation project (*jishu kaifa xiangmu*) that was carried out between 1985 and 1992. These technology projects were for the express purpose of renovating or moderniz-

[1]Collectively-owned enterprises are firms that were established, owned and managed by lower levels of governments. In our sample, they include firms owned by the Shanghai government, as well as outlying counties and townships that formally made up the municipality of Shanghai. Joint ventures are usually formed by Chinese firms (state-owned or collectively-owned) and foreign partners. Provisions for multi-year tax holidays and expanded autonomy for joint ventures provided state-owned and collectively-owned firm managers additional incentives to find offshore investors and technology suppliers.

ing the production operations of a firm. Because firms were concerned about disclosing 'proprietary' information, we limited ourselves only to the projects carried out before 1993. However, this provides us a minimum of two years of performance for each project.

2.2. Shanghai

Historically, Shanghai was the center of Chinese industry and the home of some of China's largest and best firms. In 1988, Shanghai firms were the source of 7.1 percent of the national gross value of industrial output and 12.3 percent of the national industry profits. On average Shanghai firms were larger, more capital intensive, experienced higher labor productivity and had higher profitability (i.e., profits per fixed assets) than firms in the rest of China. In addition, Shanghai has much higher concentration of state-owned enterprises. Nationally, the share of gross value of industrial output produced by state-sector firms was 56.8 percent. In Shanghai, however, the percentage was considerably higher, 70.5 percent. In turn, the collective sector and non-state sectors were smaller in Shanghai.

Over the period of our study, Shanghai was also an important beneficiary of China's opening-up policy. Between 1988 and 1992 foreign capital flows into Shanghai totaled more than $US 6.0 billions, or slightly less than 10 percent of total national flows over the same period (*Zhongguo Jingji Tongji Nianjian*, select years). Much of the foreign investment was going into manufacturing industries and primarily through joint ventures.[2]

Over the same period, technology imports from advanced countries played an increasingly important role in the modernization of Chinese firms in general. Between 1983 and 1992, Shanghai firms signed 2,512 technology import contracts, of which 1,175 had started

[2]The rest came through cooperative production ventures (*hezuo jingying qiye*) and wholly-owned and independent foreign ventures (*duzi jingying qiye*).

production by 1992. Up through 1992 the cumulative value of these agreements (which presumably includes the value of capital equipment) was $US 2.5 billions, of which 23.9 percent was with firms from Japan, 20.5 percent was with Germany, and 15.4 percent was with the United States (*Shanghai Tongji Nianjian*, select years).

2.3. Firms' Operations and Market Environment

Our survey covers an important period of China's economic reform. In the early 1980s China began a systematic effort to reform its industrial enterprises (Naughton 1995). Firms that were largely owned and controlled by the state were given new autonomy over production decisions and provided more powerful economic incentives. For example, they were allowed to retain a portion of their profits and to provide bonuses to managers and workers. At the same time, the central government reduced barriers to entry in many sectors, and relaxed controls over prices of most products and inputs through the introduction of the dual-track system (Byrd 1991, Lau, Qian and Roland 2000). As a result, most state-owned firms faced increasing product market competition.

There has been considerable debate in the literature over the effect these reforms had on state-owned enterprise behavior and productivity vis-à-vis their non-state owned counterparts, especially up through the early-to-mid 1990s (Lardy, 1998). The general consensus now appears to be that although these reforms helped to alter the behavior of state-owned firms and improve their performance (Groves *et. al.* 1994, Li 1997, Shirley and Xu 2000), productivity growth and profitability continued to lag significantly behind firms in the non-state sector (Jefferson and Rawski 1996). Soft budget constraints facing state-owned firms (i.e., firms know *ex-ante* that they will be able to default on their debt in the event of project losses) appear to be the likely cause.

Over the period we are examining, China's financial system was dominated by four state-owned banks, which held more than 80 percent of the assets of the financial system. Lending by these banks was largely administratively determined through the national credit plan, and heavily biased in favor of state-owned firms. Up through the early 1990s, between 85-90 percent of all lending by the state-owned banks consistently went to the state-owned firms in the form of working capital and fixed investment loans (*Jinrong Nianjian*, select years, Brandt and Zhu 2000).[3] There was a significant subsidy component implicit in lending. Real interest rates were low, and in fact occasionally negative (Lardy 1998). Soft budget constraints further reduced the effective borrowing costs facing these firms. The bias in bank lending towards state-owned firms and budget softness can be linked to their size and their responsibility for worker welfare, including housing, health services, retirement benefits, etc.[4] The legacy of soft-budget constrains is a banking system with perhaps as much of a half of its portfolio non-performing (Standard & Poors Credit Week, June 11, 2003).

The effects of the industrial reform are evident in our data. Table 1 summarizes self-reported information on firms' objectives, product pricing, factors affecting profitability, and barriers to investment. With respect to firm objectives and product market competition, the differences between state-owned firms and firms in the non-state sector appear modest during the period of our study.

Firms were asked to list their top three objectives. Panel A of Table 1 reports the

[3]Paralleling the high percentage of credit going to state-owned enterprises, nearly two-thirds of all investment in economy over this period was in the state sector.

[4]Although state-owned firms were inefficient, the political costs of hardening budgets and cutting off funding during this period were still high. On this point, see Shleifer and Vishy (1994).

four most-cited objectives. ‘Reducing production costs’ and ‘achieving economies of scale through market expansion’ were the top objectives of more than two-thirds of all types of firms, which suggests that improving firm profitability is a goal common to all ownership types. Our data also provide some support for changes in price regulation. As shown in panel B, more than half of state-owned and collectively-owned firms and 84 percent of joint ventures reported that the prices of their main products were determined by market forces. In contrast, just 11 percent of state-owned and collectively-owned firms reported that the supervisory agency sets mandatory prices.

Firms were also asked to assess the major factors affecting firm profitability. As displayed in panel C of Table 1, the majority of all types of firms listed ‘competition from domestic firms’ as an important factor. In contrast, less than one-third of firms considered ‘government interference’ as a significant factor influencing firm profitability. Hence, most firms considered their production decisions to be affected more directly by domestic market competition than by government intervention.

Although there were tremendous changes in the product markets in the late 80s and early 90s, economic reform in the financial sector largely lagged behind. This imposed serious constraints on firm investment and profitability. This point is also evident in our data. As reported in panel C, over 80 percent of firms consider ‘availability of funds’ as an important factor affecting profitability. Panel D of Table 1 shows that for the majority of all types of firms, ‘insufficient internal funds’ and ‘difficulty in getting bank loans’ were major barriers to investment. However, firms differed greatly by ownership in the ability to access external funds (mainly bank loans) and the hardness of budget constraints.

2.4. Firm Attributes

Table 2 provides summary statistics on firm attributes with respect to firm age, size, physical capital intensity, human capital, and firm profitability. The left panel of the table displays information for the full sample of 248 firms. The right panel reports on a smaller sample that only includes firms with information on employment, profits, output, and fixed assets prior to the technology project.[5] For state-owned and collectively-owned firms, the differences between the two samples are small in general. However, joint ventures in the smaller sample appear to be less capital-intensive, and have lower profits per worker than those in the full sample. In the empirical analysis we mainly exploit the smaller sample to control for intrinsic firm attributes. This is because most technology projects involve large investment in fixed assets, which would have substantial effects on firm physical capital intensity, profits, and other firm performance after the project.

As shown in Table 2, the data reveal considerable firm-level heterogeneity – both within and across ownership groups. State-owned firms are substantially older and larger than either collectively-owned firms or joint ventures. On the other hand, joint ventures are significantly more capital intensive than other firms. This is complemented by greater human capital in the joint ventures. Thus, joint ventures have higher firm profitability than other firms, as expected.

[5]The reduction of sample size arises from three sources. First, 9 state-owned firms, 15 collectively-owned firms and 29 joint ventures were established at the same time as the project, and so we do not have the information on firms themselves prior to the project. Second, 6 state-owned firms, 5 collectively-owned firms and 1 joint venture had projects that started before 1987, but firms were only asked to report data retroactively up to 1987. Finally, 6 state-owned firms, 4 collectively-owned firms, and 4 joint ventures did not report information on firm profits, fixed assets or output prior to the project.

2.5. Technology Projects

In this paper we focus on technology projects. For all types of firms, the primary purpose of technology projects was either to introduce 'new' products or improve the quality of existing products. ('New' products here mean the products that are new to the firm but not necessarily new to the entire product market.) This process of renovating or modernizing the production operations is crucial for a firm to succeed in intensified product-market competition.

Table 3 reports project size, a breakdown of project expenditure, sources of project financing, and project performance. On average, state-owned firms have substantially larger projects than joint ventures and especially collectively-owned firms. This is consistent with the large firm size of those state-owned firms. The investment carried out as part of the technology projects represents a significant portion of the fixed productive assets. For state-owned firms, the median size of new investment is 31 percent of the firm's assets at the time when the project begun, while it constitutes 50 percent for collectively-owned firms and 41 percent for joint ventures. Clearly, the economic success of these firms is tied to the success of these projects, which helps justify our focus on these renovation projects.

For all types of firms, equipment (including domestic and imported) constitutes between 57 percent and 79 percent of total project expenditure. State-owned firms and joint ventures, however, are much more likely to import equipment: 75 percent of state-owned firms and 63 percent of joint ventures imported equipment, compared to only 42 percent of collectively-owned firms that did. This behavior translates into a larger average share of investment in imported equipment for the state-owned firms and joint ventures. The origin of imported equipment is mainly from technologically-advanced countries including the United States, Japan, and Germany.

Most firms consider the availability of funds as a major factor affecting their investment and profitability. However, firms differ significantly in their ability to access external funds. As displayed in Table 3, 84 percent of state-owned firms used bank loans while 63 percent of collectively-owned firms and just a half of joint ventures obtained bank loans to finance their technology projects. On average, bank loans covered 46 percent of project expenditure for state-owned firms, but only 29 percent for collectively-owned firms and 36 percent for joint ventures. The enormous size difference in these projects across ownership groups implies that a majority of the credit was going to state-owned firms.

The bottom of Table 3 reports project performance in terms of project profitability and capacity utilization rates. Project profitability is measured by gross project profits relative to project size. By 1993, project profitability is the lowest for state-owned firms but the highest for joint ventures. State-owned firms also have the lowest capacity utilization rates.

To summarize, we find that (1) firms differ substantially in terms of size, age, human capital and physical capital intensity. These attributes capture a firm's capability to absorb a 'new' technology; (2) firms differ greatly in the ability to access external funds. In particular, state-owned firms have better access to cheap bank credits than other firms; (3) compared to other ownership types, state-owned firms adopt much larger projects and invest more in imported equipment; and (4) state-owned firms appear to have poorer project performance than other firms. In the following we will present a theoretical framework in which the difference in investment behavior and subsequent project performance is linked to the difference in technical capacity and the ability to access bank loans.

3. Theoretical Framework

In this section we present a simple theoretical framework to examine firm investment decisions. We assume that all firms are profit-maximizers. This is a simplifying assumption. It is likely that state-owned firms have other objectives such as maximizing output or employment. However, based on the discussion in section 2.3, the industrial reforms in the late 80s and early 90s increased the weight state-owned firms put on improving profits compared to fulfilling output quotas or other planned targets.

Firms differ in the capability to absorb new technology. Let θ_i denote firm i's technical capacity. Firms also differ substantially in the ability to access funds. The major sources of project financing come from bank loans and internal funds.[6] Let r^B be the interest rate charged by banks, and r^I the opportunity cost of internal funds. Because bank loans are a form of government subsidy to firms, we assume that $r^B < r^I$.[7] This is contrary to the usual assumption that the cost of internal funds is lower than that of external funds due to adverse selection or moral hazard problems (e.g., Johnson, McMillan, and Woodruff 2002). This difference between r^B and r^I implies that a firm will first seek bank loans before using their internal funds to finance their projects. How much credit a firm can obtain is determined by banks on the basis of firm characteristics (mainly ownership and size). Let b_i be the fraction of project expenditure that is financed through bank loans for firm i. A higher b_i indicates that a firm has better access to bank loans.[8] Then the effective interest

[6]Foreign investment covered 20 percent of project expenditures for joint ventures (see Table 3). For simplicity, we treat foreign investment as equivalent to internal funds in terms of the opportunity cost of investment.

[7]Bank loans here play a role of government transfer in the model of Shleifer and Vishy (1994). Moreover, although our model does not explicitly deal with soft budget constraints, our results should hold in their presence since soft budget constraints essentially lower the interest rate charged by banks (Dewatripont and Maskin 1995).

[8]A regression of access to bank loans (i.e., the fraction of project expenditure that is financed through

rate for firm i is $b_i r^B + (1 - b_i) r^I$.

Let k_i be firm i's project investment, and p the price of capital goods. Let $R(k_i)$ be the expected project revenue in each period, and $C(k_i, \theta_i)$ the expected cost of operating new technology in each period. The expected project profit in each period is $R(k_i) - C(k_i, \theta_i)$. Thus, the present value of expected project profits is $[R(k_i) - C(k_i, \theta_i)] / [b_i r^B + (1 - b_i) r^I]$. Note that the current capital stock is suppressed in $R(k_i)$ and $C(k_i, \theta_i)$. All variable inputs are optimally chosen. For simplicity, we also omit depreciation, taxes, and costs of adjusting the capital stock. In addition, we do not consider any strategic interaction between firms. Then the firm's investment problem can be characterized as

$$\max_{k_i} \frac{R(k_i) - C(k_i, \theta_i)}{b_i r^B + (1 - b_i) r^I} - p k_i.$$

In order to have an interior solution to this problem, we make the following assumptions: (i) $R(k_i)$ is continuously differentiable, strictly increasing, and strictly concave; (ii) $C(k_i, \theta_i)$ is continuously differentiable, strictly increasing in k_i, strictly decreasing in θ_i, and strictly convex for any given θ_i; and (iii) $R(0) - C(0, \theta_i) = 0$ and $\lim_{k_i \to 0} R'(k_i) - C'_{k_i}(k_i, \theta_i) > 0$. Assumptions (i) and (ii) guarantee that the second-order condition holds, i.e., $R''(k_i) - C''_{k_i}(k_i, \theta_i) < 0$.

The first-order condition for the firm's problem is

$$R'(k_i) - C'_{k_i}(k_i, \theta_i) = [b_i r^B + (1 - b_i) r^I] p. \tag{1}$$

bank loans) on firm attributes reveals that larger firms in terms of the number of workers and fixed assets prior to the project obtained relatively more bank loans to cover their project expenditure. On the other hand, access to bank loans does not appear to be related significantly to firm age, sector, and firm profitability and output prior to the project.

That is, firms choose the optimal investment $k_i^*\left(\theta_i, b_i, r^B, r^I, p\right)$ by balancing the marginal return to investment against the user cost of capital. Based on this first-order condition, it is straightforward to derive the effect of technical capacity (θ_i) and the ability to access bank loans (b_i) on project size as follows:

$$\frac{\partial k_i^*}{\partial b_i} = \frac{p\left(r^B - r^I\right)}{R''\left(k_i\right) - C''_{k_i}\left(k_i, \theta_i\right)}, \tag{2}$$

$$\frac{\partial k_i^*}{\partial \theta_i} = \frac{C''_{k_i,\theta_i}\left(k_i, \theta_i\right)}{R''\left(k_i\right) - C''_{k_i}\left(k_i, \theta_i\right)}. \tag{3}$$

The implications of equations (2) and (3) are summarized in proposition 1.

Proposition 1. *(Technology Adoption)*

(i) If $r^B < r^I$, then $\partial k_i^*/\partial b_i > 0$. In addition, $\partial k_i^*/\partial b_i$ increases in $\left(r^I - r^B\right)$.

(ii) If $C''_{k_i,\theta_i}\left(k_i, \theta_i\right) < 0$ (i.e., k_i and θ_i are complementary), then $\partial k_i^*/\partial \theta_i > 0$.

That is, firms with better access to bank loans and higher technical capacity adopt larger projects. The magnitude of the effect of bank loans on project size depends on the gap between r^B and r^I, which is largely determined by ownership types. Since subsidies are more important in loans to state-owned firms, the gap between r^B and r^I is larger for state-owned firms than other firms. Thus, we expect that the impact of bank loans on project investment would be the strongest for state-owned firms.

We are also interested in the impact of θ_i and b_i on project performance. One performance measure is project profitability which is a ratio of project profits to project size, i.e., $\pi_i \equiv \left[R\left(k_i^*\right) - C\left(k_i^*, \theta_i\right)\right]/pk_i^*$. The ability to access bank loans (b_i) affects project profitability via its impact on technology choice (k_i^*). Using the first-order condition in equation (1), it is straightforward to derive the effect of b_i on π_i as follows:

$$\frac{\partial \pi_i}{\partial b_i} = \frac{\partial \pi_i}{\partial k_i}\frac{\partial k_i}{\partial b_i} = \frac{\left[R\left(k_i^*\right) - C\left(k_i^*, \theta_i\right)\right] - \left[b_i r^B + \left(1 - b_i\right) r^I\right] p k_i^*}{\left(k_i^*\right)^2 \left[R''\left(k_i\right) - C''_{k_i}\left(k_i, \theta_i\right)\right]} \left(r^I - r^B\right). \tag{4}$$

The implication of equation (4) is summarized in proposition 2.

Proposition 2. *(Technology Absorption)*

If $r^B < r^I$, *then* $\partial \pi_i / \partial b_i < 0$. *In addition,* $\partial \pi_i / \partial b_i$ *decreases in* $\left(r^I - r^B\right)$.

That is, given the same technical capacity, firms with better access to cheap bank loans have lower project profitability. This is because firms with better access to cheap credit choose larger projects, which increases the costs of adopting and using new technology and thus reduces the rate of project profits.

Technical capacity has two opposing effects on project profitability. The indirect effect works through its impact on project size: firms with higher technical capacity choose larger projects. This raises the costs of adoption and absorption and hence lowers profitability. On the other hand, higher technical capacity *directly* reduces the cost of using new technology and thus raises profitability. If this direct effect dominates, firms with higher technical capacity have higher project profitability.

The previous discussion has focused on the total project investment. Inspired by the literature on the relationship between importing equipment and economic growth (e.g., De Long and Summers 1991, Eaton and Kortum 2001), we extend our theoretical framework to examine the choice between imported and domestic equipment. The basic idea is similar to that is given in proposition 1. Since formalizing this problem requires a new set of notation, a detailed theoretical presentation is relegated to the appendix. Now we focus on the intuition instead.

We expect that imported and domestic equipment have different effects on project revenues as well as costs of adopting and operating new technology. On the one hand, imported equipment is likely to embody more advanced technology, which allows a firm to produce better products and achieve higher project revenues. On the other hand, imported equipment is likely to be more expensive to adopt. In addition, a higher share of imported equipment may increase the difficulty in absorbing new technology, leading to higher costs of using new technology. Under certain assumptions, the results in proposition 1 also hold for investment in imported and domestic equipment. Interestingly, the modified model also implies that with better access to bank loans, firms increase investment in imported equipment more than in domestic equipment. These results are summarized in proposition 3 in the appendix.

This completes our discussion about the theoretical model. This model provides a basis for the following empirical analysis.

4. Technology Adoption

In this section we focus on project size and investment in imported and domestic equipment. As suggested by proposition 1 and proposition 3 in the appendix, firm investment decisions are determined by technical capacity (θ_i) and the ability to access bank loans (b_i). Since the effect of b_i on investment depends on the wedge between r^B and r^I, which is mainly determined by ownership types, we include the interaction term between b_i and ownership types (see equations (2), (10) and (11)). Our empirical specification is

$$tech\ choice_i = f\left(ownership_i,\ b_i \cdot ownership_i,\ \theta_i,\ Z_i\right) + \mu_i \tag{5}$$

where i indexes firms; $tech\ choice_i$ represents project size or investment in imported and domestic equipment; $ownership_i$ indicates ownership types; b_i is the fraction of project expenditure that is financed through bank loans; θ_i is a vector of variables measuring technical capacity including firm size, age, human capital, and physical capital intensity; Z_i is a vector of other control variables including firm profitability (proxy for the availability of internal funds), sector dummies, and time dummies indicating the year when the project started (proxy for investment opportunities facing all firms); and μ_i is the error term.

We only use as controls firm attributes prior to the project.[9] Unfortunately, this reduces our sample from 248 firms to 169 firms for reasons explained earlier (see footnote 5). In particular, about two-thirds of the joint ventures drop out of the sample, which seriously restricts our ability to analyze the behavior of joint ventures.

4.1. Project Size

Results on project size are reported in Table 4. The dependent variable is the logarithm of project size. Column 1 shows that state-owned firms have significantly larger projects than collectively-owned firms even after controlling for sector and the year in which the project

[9]Data on worker education are only available for the year 1994. However, between 1992 and 1994, the average annual turnover rate in our sample of firms was below 1.4 percent (the median was below 0.8 percent) for managers and below 3.6 percent (the median was below 1.9 percent) for production workers. Thus, we expect that educational levels of workers were very similar before and after the project. In addition, our estimation reveals that worker education does not affect investment significantly. Excluding worker education from our regressions has no significant effect on our other results.

started.

Column 2 adds three measures of firm size – fixed productive assets, output, and employment prior to the project. The impact of firm size on innovation and technology diffusion has been examined extensively (e.g., Cohen and Levin 1989). A larger firm can better reap the benefit of adopting a new technology due to economies of scale. A larger firm may also have more internal sources, be more diversified, and be better able to hedge against the risks associated with technology adoption. Moreover, the accelerator model in the investment literature supposes that higher sales or output lead to higher level of investment. The replacement model assumes that firms with more capital assets have higher demand for investment due to the need of capital replacement. Thus, our specification nests the different models in the literature. Note that all of the models predict that larger firms should adopt bigger projects. Indeed, column 2 shows that all three measures of firm size have a positive effect on project size. In particular, firms with more fixed productive assets and higher output prior to the technology project adopt significantly larger projects. The coefficient on 'state-owned firm' becomes insignificantly negative.

A firm's technological capacity is related to their physical capital intensity, human capital and the vintage of existing technology. Human capital is captured by worker education. The vintage of the firm's existing technology is proxied by firm age. The estimates in column 3 show that physical capital intensity, worker education and firm age are not significantly correlated with project size.[10] As will be shown in the next section, however, physical capital intensity is significantly and positively correlated with expenditure on imported equipment but not on domestic equipment. The insignificant effect of human capital and technology

[10] Employment is excluded to avoid multicollinearity.

vintage may be due to measurement errors. Worker education may fail to capture firm-specific human capital, which is also crucial for technology absorption. The use of firm age as a proxy for technology vintage ignores the fact that older firms may upgrade their technology.

Since 'insufficient internal funds' and 'difficulty in getting bank loans' are the biggest barriers to firm investment (see Table 1), we are particularly interested in how the ability to access funds affects project size. In column 4, we include firm profitability i.e., the ratio of firm profits to fixed assets, as a proxy for the availability of internal funds. We find no evidence that firm profitability prior to the project has a significant effect on project size when we also control for firm size and other firm attributes.

In column 5 we add interactions between access to bank loans and firm ownership. Access to bank loans is measured by the fraction of project expenditure that is financed through bank loans. This measure is demeaned so that the estimated coefficient on 'state-owned firm' (or 'joint venture') indicates whether the size of the projects of state-owned firms (or joint ventures) is significantly different from that of collectively-owned firms if the two types of firms can access bank loans at the average level. Note that using demeaned bank loans does not affect the estimates of the interaction terms between bank loans and ownerships. Interestingly, the estimated coefficient on the interaction between bank loans and 'state-owned firm' suggests that a 1 percentage point increase in the share of bank loans is associated with a 1.38 percent increase in project size for state-owned firms. This is consistent with our theoretical prediction that firms with better access to bank loans adopt larger projects.

At the same time, the estimated coefficient on the interaction between bank loans and ‘collectively-owned firm’ is positive, although it is not statistically significant and its magnitude is also just a third of that for state-owned firms. This difference between state-owned and collectively-owned firms can be explained by the fact that bank loans are more important as a form of government subsidy to state-owned firms than to collectively-owned firms. That is, the wedge between the cost of bank loans and that of internal funds is much larger for state-owned firms than for collectively-owned firms. Therefore, the ability to access bank loans affects state-owned firms much more than collectively-owned firms.

We also find that for joint ventures, a 1 percentage point increase in the share of bank loans is related to a 1.50 percent *decrease* in project size. This is contrary to our theoretical prediction. One explanation is that the cost of bank loans may in fact be higher than the cost of internal funds for joint ventures. Alternatively, for joint ventures bank loans are mainly used to purchase domestic equipment, which is cheaper than imported equipment. (Unlike other firms, joint ventures can use foreign investment to finance their purchases of imported equipment.) So joint ventures that use more bank loans to finance their projects also have smaller projects. We will provide empirical evidence that supports the second interpretation.

There is concern that our measure of bank loans may be endogenous; banks may decide to finance larger and better projects. However, according to the literature on credit rationing in China, lending by China’s state-owned banks is more heavily influenced by government policy than project profitability. In fact, during this period banks lacked the expertise to choose good projects that were well matched with firm capability. Banks incentives to select good projects over bad ones were also often weak (Brandt and Li, forthcoming). Therefore, we are inclined to believe that the link between the quality of projects and the size of bank loans is weak. In addition, due to data limitation, we do not have a more convincing measure of a firm's ability to access bank loans. Hence, we interpret our result on the relationship between bank loans and project size as correlation rather than causality.

We also experiment with other measures of bank loans. Column 6 reports the estimates when 'bank loan' is a dummy variable, which equals 1 if the firm obtained bank loans to finance the technology project. As it is apparent, the results are very similar to the benchmark estimates in column 5.

Finally, in all of the specifications in Table 4, we control for firm sector and the year when the technology project started. (To save space, these results are not reported in the table.) Projects tend to be significantly larger (smaller) than average in the transportation (chemical) industry.[11] We also find that the projects that were carried out after 1989 are significantly smaller in size than those projects implemented before 1989. This result is consistent with the economic retrenchment beginning late in 1988. For the next several years, tight monetary policy was implemented in order to combat inflation. Firm profitability was also lower. This shortage of funds tended to reduce project size.

4.2. Investment in Imported versus Domestic Equipment

As suggested by proposition 3 in the appendix, technological capability and the ability to access bank loans have disparate effects on investment in imported and domestic equipment. Thus, in this section we study investment in imported and domestic equipment separately. Results are given in Table 5.

[11]Most of the projects in transportation were linked to the development of Shanghai's emerging auto industry. The key venture was a joint venture between Germany Volkswagen and Shanghai Automotive Industrial Corporation, complemented by investment in new and existing parts suppliers.

Columns 1-2 report simple OLS estimates. A comparison between imported and domestic equipment reveals several interesting results. First, for state-owned firms, a 1 percentage point increase in the share of bank loans is associated with a 2.13 percent increase in the expenditure on imported equipment but just a 0.07 percent increase in the purchase of domestic equipment. This is consistent with our theoretical prediction that with better access to cheap bank loans, firms increase investment in imported equipment more than in domestic equipment. For collectively-owned firms, we also find that the estimated coefficient on bank loans is larger for imported equipment than that for domestic equipment. In contrast, for joint ventures, a 1 percentage point increase in the share of bank loans is related to a 2.23 percent *decrease* of investment in imported equipment but a 1.83 percent *increase* in domestic equipment. Therefore, unlike state-owned and collectively-owned firms, bank loans lent to joint ventures appear to be tied to the purchase of domestic equipment. This difference may be due to the fact that joint ventures can use foreign investment to purchase imported equipment. However, for both collectively-owned firms and joint ventures, the coefficients on bank loans are not statistically significant.

Second, more profitable firms invest more in imported equipment. The estimate implies that a 1 percent increase in firm profitability is associated with a 0.42 percent increase in expenditure on imported equipment. In contrast, the estimated coefficient on firm profitability for domestic equipment is small and statistically insignificant. Firm profitability indicates the availability of internal funds. Profitability may also be linked to efficiency of the firm. Thus, the result provides some evidence that better firms adopt more advanced technology.

Third, more capital-intensive firms purchase less domestic equipment. Capital intensity represents the production technique of a firm. Compared to labor-intensive firms, capital-intensive firms are likely to equip their workers with more sophisticated machinery. Their workers may also have greater experience with more capital-intensive and technologically advanced production processes.[12] Thus, more capital-intensive firms are likely to have lower demand for domestic equipment.

Fourth, firms with more fixed productive assets prior to the project spend relatively more on imported than domestic equipment. In particular, the estimates suggest that a 1 percent increase in fixed assets is related to a 0.95 percent increase in expenditure on imported equipment and a 0.60 percent increase in expenditure on domestic equipment. The statistical significance is also higher for imported equipment than that for domestic equipment.

Because 61 firms did not purchase any imported equipment and 43 firms did not invest in domestic equipment, we also use the left-censored Tobit model to take into account the problem of corner solutions. Results are displayed in columns 3-4. The Tobit estimates have similar signs and significance levels as the OLS estimates, and the estimated marginal effects are also quite similar to the OLS estimates. For example, the estimate in column 3 implies that for state-owned enterprises, the marginal effect of access to bank loans on expected investment in imported equipment is 1.74 (evaluated at the mean values of the covariates). This marginal effect is slightly lower than the OLS estimate of 2.13 in column 1. The estimated marginal effect of firm profitability on the purchase of imported equipment is 0.49, which is slightly higher than the OLS estimate of 0.42. Thus, the Tobit estimates

[12] The simple correlation between capital intensity and the percentage of workers with college degree or above is 0.23 (p-value=0.002), while the simple correlation between capital intensity and the percentage of workers with junior high-school diploma is -0.15 (p-value=0.05). This provides preliminary evidence that capital and skills are complementary.

in columns 3-4 confirm our previous results.

In column 5 we examine the share of expenditure on imported equipment. Unlike total expenditure on imported equipment, access to bank loans is not significantly correlated with the expenditure share of imported equipment for state-owned firms. On the other hand, more capital-intensive and more profitable firms have significantly higher share of imported equipment. This is consistent with the results in columns 1-2 that profitable firms invest more in imported equipment while capital-intensive firms invest less in domestic equipment.

So far we have implicitly assumed that a single mechanism drives the decisions about whether to import equipment and how much to import. It is possible that technical capacity and the ability to access bank loans may have different effects on the decision to import equipment and conditional on importing, the decision as to how much to import. To address this issue, in columns 6-7 we report the estimates of a two-tiered model. The first tier is whether to import equipment or not, as shown in column 6. Conditional on positive purchase of imported equipment, we then examine the decision about how much to import. The OLS estimate is illustrated in column 7.

We find that access to bank loans does not affect the decision to import equipment. This is true even for state-owned firms. However, when conditioning on positive investment in imported equipment, access to bank loans is significantly and positively correlated with the expenditure on imported equipment for state-owned firms. The estimate of 2.08 in column 7 is fairly close to the estimate of 2.13 in column 1 for the whole sample. In contrast, the effect of bank loans becomes much stronger for collectively-owned firms when conditioning on positive purchase of imported equipment. For joint ventures, access to bank loans still has a negative effect on investment in imported equipment. In addition, profitable firms are more likely to import equipment. However, once we condition on positive investment in imported equipment, firm profitability does not appear to affect the decision on how much to import. On the other hand, firms with more fixed assets are more likely to import and also spend more on imported equipment.

Finally, in all specifications in Table 5 we control for sector and the year in which the technology projects started. Interestingly, we find that investment in domestic equipment appears to be more volatile and more influenced by macroeconomic fluctuations. In contrast, investment in imported equipment is fairly stable over time. Furthermore, transportation, electrical equipment and machinery, and electronic and telecommunications equipment industries have significantly higher investment in imported equipment than the chemical industry. However, investment in domestic equipment does not appear to vary substantially across sectors.

To summarize, we find that although the economic reform pushed firms to face more competition in product markets, the government still exerted influences on firm investment decisions through project financing. In particular, easy access to cheap bank credit encouraged state-owned firms to adopt bigger projects and invest more in imported equipment. At the same time, we also find that firms with more fixed assets and higher output prior to the project adopt bigger projects; more profitable firms invest more in imported equipment while labor-intensive firms invest more in domestic equipment. Thus, technical capacity also plays a role in affecting investment decisions.

5. Technology Absorption

To evaluate project performance, we mainly exploit two measures – project profitability (i.e., a ratio of gross project profits to project size) and capacity utilization rates. Both measures will be a product of the technical capabilities of the firm, and the commercial soundness of the project. Empirically, it is often hard to separate the technological side from the commercial side. Our measure of project profitability corresponds to the π_i in the theoretical model.

The survey provides us a panel of data on project gross profits and capacity utilization rates between 1987 and 1995. Since firms started their technology projects in different years, the panel is unbalanced. On average we have only 2 to 3 years of observations about project performance. Thus, our evaluation mainly captures project performance in the short run. Since larger projects take longer for firms to absorb fully and operate 'new' technology efficiently, our results are likely to be biased against larger projects. On the other hand, for 15 percent of the firms, we have 4 years of data on project performance and for 23 percent of the firms we have 5 years or more. This allows us to evaluate project performance over a 5-year horizon.

5.1. Project Profitability

As suggested by proposition 2 in section 3, project profitability is influenced by the ability to access bank loans. The effect of bank loans works through their impact on technology choices. The discussion in section 3 also suggests that technical capacity has two opposing effects on project profitability. Thus, the empirical specification is as follows:

$$\pi_{it} = ownership_i \beta_1 + b_i \cdot ownership_i \cdot \beta_2 + \theta_i b_3 + Z_{it}\beta_4 + \varepsilon_{it} \tag{6}$$

where i indexes firms; t indexes years; π_{it} is project profitability which is a ratio of project gross profits to project size; Z_{it} include firm profitability prior to the project (proxy for internal funds), and a vector of dummy variables controlling for sector, year and duration of the project; and ε_{it} is the error term. The definitions of $ownership_i$, b_i and θ_i are the same as those in equation (5). Our main interest is in the reduced-form effect of the ability of the firm to access bank loans on project profitability, β_2.

There is one caveat about our measure of project profitability. For the projects that produce new products, project profits are well defined.[13] However, some of the technology projects involve products that are related to the existing products produced by the firm. In this case it becomes difficult to measure accurately project profits. Thus, our measure of project profitability is likely to have measurement error. However, if the measurement error of project profitability is not systematically correlated with our measures of firm technical capacity and the ability to access bank loans, the measurement error of project profitability should not bias our estimates since it can be absorbed by the error term in the regression.[14]

Pooled OLS estimates are displayed in columns 1-2 of Table 6. In column 1, the estimated coefficient on the interaction between bank loans and 'state-owned firm' is -2.30 with a t-

[13]In our sample, 59 percent of state-owned firms, 58 percent of collectively-owned firms, and 69 percent of joint ventures have technology projects that involve new products.

[14]We also estimate equation (6) controlling for whether the project involves new products. We find no evidence that projects involving new products have significantly higher or lower profitability than the projects that involve products related to existing ones.

statistic of 3.56, indicating that for state-owned firms a 1 percentage point increase in the share of expenditure that is financed through bank loans is associated with a 2.30 percent decrease in project profitability. This result lends support for the theoretical prediction that given technical capacity, firms with better access to cheap bank credits have lower project profitability.

At the same time, for collectively-owned firms the partial correlation between the ability to access bank loans and project profitability is small and statistically insignificant. This result is consistent with the previous finding that access to bank loans is not significantly correlated with project size for collectively-owned firms. These results may suggest that the cost of bank loans is close to that of internal funds so that access to bank loans should not have any significant effect on investment and thus, project performance. Furthermore, for joint ventures the access to bank loans is weakly and positively related to project profitability. Therefore, we find that unlike state-owned firms, bank loans do not appear to be a form of subsidy to either collectively-owned firms or joint ventures.

Column 1 also shows that more profitable and more capital-intensive firms have higher project profitability. Note that firm profitability may not only capture the availability of internal sources, but also be related to managerial effectiveness and other firm attributes that also contribute to higher project profitability. At the same time, the estimates of the coefficients on project length indicate that project profitability improves over the life of the project. In particular, project profitability is approximately 1.24 times higher for projects with 5 (or above) years of operation than for start-up projects. This increase in profitability is also statistically significant. This result suggests that firms may improve their production efficiency through learning by doing. The result may also be driven by an increase in the market share of a project's products.

In order to examine whether a higher share of imported equipment increases the cost of absorption and thus lowers project profitability, in column 2 we add the share of expenditure on imported equipment.[15] We find that a 1 percentage point increase in the share of imported equipment in fact raises project profitability by 0.77 percent, although this effect is not statistically significant. The positive effect of investment in imported equipment reflects that although imported equipment may increase the difficulty in absorbing technology and raise the demand for more expensive imported intermediate inputs,[16] imported equipment may also allow a firm to produce better products and achieve larger market shares.[17] This latter effect increases sales and profits, thus offsetting the negative effect of higher absorption costs associated with imported equipment.

Even though we have controlled for various firm attributes in columns 1 and 2, it is still possible that some unobserved firm effects are influencing project profitability. Since the share of bank loans and other firm attributes in our specification are time invariant, we cannot use fixed-effects estimation. Columns 3-4 report random-effect estimates. In this case, the unobserved firm effects are assumed to be uncorrelated with the ability to access bank loans and other firm attributes. As it is apparent, the random-effect estimates are fairly similar to those from the pooled OLS regressions. The only major difference is that the share of imported equipment becomes more significantly correlated with project

[15]We also estimate equation (6) including the interaction between ownership and the share of expenditure on imported equipment. However, the estimated coefficients do not differ significantly across ownership types. Thus, we only report the results without the interaction.

[16]Our data reveal that controlling for sector and the year when the project started, a 1 percentage point increase in the expenditure share of imported equipment is related to a 0.28 percent increase in the share of imported intermediate inputs during the initial period of the project (p-value = 0.10).

[17]This is supported by the positive correlation between the expenditure share of imported equipment and the market share of project products (0.16 with a p-value of 0.05).

profitability.

To deal with the possible correlation between unobserved firm effects and other firm attributes, we also experiment with the Hausman-Taylor estimator. In this specification, we allow for the possibility that firm profitability, size, physical capital intensity, and the access to bank loans are correlated with the unobserved firm effect. Results are given in columns 5-6. Most estimates become much less precise. However, as shown in column 5, our key results still hold qualitatively. In particular, state-owned firms with better access to bank loans have lower project profitability. In contrast, for both collectively-owned firms and joint ventures, the estimated coefficients on bank loans are positive. The effect of bank loans on project profitability also differs significantly between state-owned firms and joint ventures. (The t-statistic is 4.46 with a p-value of 0.03.) In column 6, although the coefficient on bank loans turns positive for state-owned firms, it is smaller than that for collectively-owned firms and much smaller than that for joint ventures.

5.2. Capacity Utilization

Another related measure of project performance is capacity utilization rates.[18] We estimate equation (6) with π_i replaced by project capacity utilization rates. As shown in Table 7, the results are largely consistent with those in Table 6. We find that state-owned firms with better access to cheap bank loans have significantly lower capacity utilization rates. However, we find no evidence that bank loans are negatively associated with capacity utilization for collectively-owned firms and joint ventures. In addition, capacity utilization rates increase over the life of the projects. On the other hand, higher shares of imported equipment do

[18]The simple correlation between project profitability and capacity utilization rates is 0.17 with a p-value of 0.001.

not appear to reduce capacity utilization.

In contrast with the results on project profitability, Table 7 also shows that state-owned firms have significantly lower capacity utilization rates than collectively-owned firms. On the other hand, firms with more fixed assets prior to the project have significantly higher capacity utilization.

To summarize, we find that state-owned firms with better access to cheap bank credits have relatively lower project profitability and capacity utilization rates. This indicates that cheap bank credits induce state-owned firms to adopt too large of projects given their technical capacity. Those bigger projects increase the costs of adopting and absorbing technology and thus reduce project profitability and capacity utilization. On the other hand, firms which are more profitable prior to the project experience higher project profitability. Firms with more fixed assets prior to the project have significantly higher project capacity utilization rates. Finally, project profitability and capacity utilization improve with the length of the project.

6. Conclusions

Using a unique firm-level survey dataset collected by one of the authors, this paper addresses two questions: what factors influence technology adoption, and how well do firms absorb 'new' technology?

We focus on technology renovation projects, which were a key component of the modernization of Chinese firms during the last two decades. Fixed investment was largely organized around these projects. Between the mid-80s and early 90s, industrial reforms had still not progressed to the point at which investment decisions were fully decentralized to firms. Largely reflecting the continued state control over the banking system, we find that access to loans from China's state-owned banks was critical to mobilizing the resources required to carry out technology projects. With better access to bank loans than other firms, state-owned firms carried out significantly larger projects and imported more technologically advanced equipment.

On the other hand, we find that project performance differs significantly across firms. State-owned firms with better access to bank loans realized significantly lower return to technology investment. An explanation for this is that state-owned firms chose projects that were too large and too advanced technology to absorb and operate efficiently.

Our empirical results have important implications for the role of financial development in technology diffusion and economic growth. Only when resources are well allocated to match technology and firms can the economy fully reap the benefits from increasing investment in technology-embodied equipment. Otherwise, investment is more likely to result in overcapacity with higher absorption costs and lower profitability.

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A. Appendix: Investment in Imported versus Domestic Equipment

Let k_i^m and k_i^d be firm i's investment in imported and domestic equipment, respectively. Let p^m and p^d be the prices of imported and domestic capital goods, respectively. Let $R\left(k_i^m, k_i^d\right)$ denote the expected project revenue in each period, and $C\left(k_i^m, k_i^d, \theta_i\right)$ the expected operating cost in each period. Similar to the discussion in section 3, the firm's investment problem can be formalized as

$$\max_{k_i^m, k_i^d} \frac{R\left(k_i^m, k_i^d\right) - C\left(k_i^m, k_i^d, \theta_i\right)}{b_i r^B + (1 - b_i) r^I} - \left(p^m k_i^m + p^d k_i^d\right). \tag{7}$$

However, since some firms in our sample did not invest in imported or domestic equipment, we will allow for corner solutions. We make the following assumptions:

Assumption 1. *$R\left(k_i^m, k_i^d\right)$ is continuously differentiable, strictly increasing in both k_i^m and k_i^d, and strictly concave; and $C\left(k_i^m, k_i^d, \theta_i\right)$ is continuously differentiable, strictly increasing in k_i^m and k_i^d, strictly decreasing in θ_i, and strictly convex for any given θ_i. (This implies that the second-order condition holds.)*

Assumption 2. $R(0,0) - C(0,0,\theta_i) = 0$, $\lim_{k_i^m \to 0} \left[R'\left(k_i^m, 0\right) - C'_{k_i^m}\left(k_i^m, 0, \theta_i\right)\right] > 0$, *and* $\lim_{k_i^d \to 0} \left[R'\left(0, k_i^d\right) - C'_{k_i^d}\left(0, k_i^d, \theta_i\right)\right] > 0$. *(This implies that firm i will invest in imported and/or domestic equipment.)*

Assumption 3. $p^m > p^d$.

Assumption 4. $R''_{k_i^m, k_i^d} - C''_{k_i^m, k_i^d} > 0$. *(i.e., k_i^m and k_i^d are complementary.)*

Assumption 5. $R''_{k_i^d} - C''_{k_i^d} < R''_{k_i^m} - C''_{k_i^m}$. *(i.e., the marginal return to investment diminishes faster for domestic equipment than for imported equipment.)*

Assumption 6. $C''_{k_i^m, \theta_i} < 0$ *and* $C''_{k_i^d, \theta_i} < 0$. *(i.e., technical capacity of the firm and adopted technology are complementary.)*

Under assumptions 1-6 we can derive the effect of b_i and θ_i on investment in imported and domestic equipment. The results are summarized in proposition 3.

Proposition 3. *(Investment in Imported versus Domestic Equipment)*

Let $k_i^{m^*}$ and $k_i^{d^*}$ denote the optimal investment of firm i in imported and domestic equipment, respectively.

(i) If $r^B < r^I$, then $\partial k_i^{m^*}/\partial b_i > 0$ and $\partial k_i^{d^*}/\partial b_i > 0$. In addition, $\partial k_i^{m^*}/\partial b_i$ and $\partial k_i^{d^*}/\partial b_i$ increase in $\left(r^I - r^B\right)$.

(ii) If $r^B < r^I$, then $\partial\left(p^m k_i^{m^*}\right)/\partial b_i > \partial\left(p^d k_i^{d^*}\right)/\partial b_i$.

(ii) $\partial k_i^{m^*}/\partial \theta_i > 0$ and $\partial k_i^{d^*}/\partial \theta_i > 0$.

Proof. (i) The first-order conditions to the firm's problem are

$$R'_{k_i^m} - C'_{k_i^m} = p^m \left[b_i r^B + (1 - b_i) r^I \right], \tag{8}$$
$$R'_{k_i^d} - C'_{k_i^d} = p^d \left[b_i r^B + (1 - b_i) r^I \right]. \tag{9}$$

Let us first consider interior solutions. In this case both $k_i^{m^*}$ and $k_i^{d^*}$ are positive and satisfy the first-order conditions. Differentiating equations (8)-(9) with respect to b_i yields

$$\frac{\partial k_i^{m^*}}{\partial b_i} = \frac{r^B - r^I}{|RC|} \left[\left(R''_{k_i^d} - C''_{k_i^d} \right) p^m - \left(R''_{k_i^m, k_i^d} - C''_{k_i^m, k_i^d} \right) p^d \right] \tag{10}$$
$$\frac{\partial k_i^{d^*}}{\partial b_i} = \frac{r^B - r^I}{|RC|} \left[\left(R''_{k_i^m} - C''_{k_i^m} \right) p^d - \left(R''_{k_i^m, k_i^d} - C''_{k_i^m, k_i^d} \right) p^m \right] \tag{11}$$

where $|RC| \equiv \left(R''_{k_i^m} - C''_{k_i^m} \right) \left(R''_{k_i^d} - C''_{k_i^d} \right) - \left(R''_{k_i^m, k_i^d} - C''_{k_i^m, k_i^d} \right)^2$. Assumption 1 implies that $|RC| > 0$, $R''_{k_i^m} - C''_{k_i^m} < 0$ and $R''_{k_i^d} - C''_{k_i^d} < 0$. Combining these results with assumption 4, we obtain that if $r^B < r^I$, $\partial k_i^{m^*} / \partial b_i > 0$ and $\partial k_i^{d^*} / \partial b_i > 0$. It is also easy to see that $\partial k_i^{m^*} / \partial b_i$ and $\partial k_i^{d^*} / \partial b_i$ increase in $\left(r^I - r^B \right)$.

(ii) Equations (10) and (11) imply that

$$\frac{\partial \left(p^m k_i^{m^*} \right)}{\partial b_i} - \frac{\partial \left(p^d k_i^{d^*} \right)}{\partial b_i} = \frac{r^B - r^I}{|RC|} \left[\left(R''_{k^d} - C''_{k^d} \right) (p^m)^2 - \left(R''_{k^m} - C''_{k^m} \right) \left(p^d \right)^2 \right].$$

Based on assumptions 3 and 5 and the implications of assumption 1, we have $\partial \left(p^m k_i^{m^*} \right) / \partial b_i > \partial \left(p^d k_i^{d^*} \right) / \partial b_i$.

(iii) Differentiating equations (8)-(9) with respect to θ_i yields

$$\frac{\partial k_i^{m^*}}{\partial \theta_i} = \frac{1}{|RC|} \left[\left(R''_{k_i^d} - C''_{k_i^d} \right) C''_{k_i^m, \theta_i} - \left(R''_{k_i^m, k_i^d} - C''_{k_i^m, k_i^d} \right) C''_{k_i^d, \theta_i} \right]$$
$$\frac{\partial k_i^{d^*}}{\partial \theta_i} = \frac{1}{|RC|} \left[\left(R''_{k_i^m} - C''_{k_i^m} \right) C''_{k_i^d, \theta_i} - \left(R''_{k_i^m, k_i^d} - C''_{k_i^m, k_i^d} \right) C''_{k_i^m, \theta_i} \right].$$

Under assumptions 1 and 4-6, it follows that $\partial k_i^{m^*} / \partial \theta_i > 0$ and $\partial k_i^{d^*} / \partial \theta_i > 0$.

Now let us consider corner solutions. Assumption 2 guarantees that firms will invest in either imported or domestic equipment. Without loss of generality, suppose that $k_i^{m^*} > 0$ and $k_i^{d^*} = 0$. In this case, equation (8) still holds. Thus, proposition 1 holds for the investment in imported equipment. ■

Table 1. Firm's Self-assessment about Operations and Market Environment

	State-owned Firms	Collectively-owned Firms	Joint Ventures
A. Firm Objectives (%)			
Reducing production costs	85	85	78
Achieving economies of scale through market expansion	62	65	70
Entering export market	54	38	68
Achieving economies of scope through product diversification	52	58	26
B. Product Pricing (%)			
Market forces determine price	56	53	84
Supervisory agency sets reference price	23	20	8
Producer's association sets minimum price	11	16	8
Supervisory agency sets mandatory price	11	11	0
C. Factors Affecting Firm Profitability (%)			
Competition from domestic firms	84	89	74
Availability of funds	80	82	80
Inability to collect debt from clients	73	68	66
Government interference	27	31	32
D. Barriers to Investment (%)			
Insufficient internal funds	85	86	62
Difficulty in getting bank loans	74	76	72
Unprofitable investment opportunities	54	39	52
Restrictions by supervisory agency	51	41	34
Number of Firms	124	74	50

Notes : This table reports the percentage of firms that select the items in the first column. For example, '62' in panel A under 'state-owned firms' indicates that 62 percent of state-owned firms consider 'achieving economies of scale through market expansion' as a top firm objective.

Table 2. Summary Statistics on Firm Attributes

	Full Sample			Smaller Sample		
	State-owned Firms	Collectively-owned Firms	Joint Venture	State-owned Firms	Collectively-owned Firms	Joint Ventures
Period Established (%)						
Pre-1978	66	26		69	30	
1979-89	19	36	30	22	42	38
1990-93	15	38	70	9	28	63
Firm Size						
Fixed Productive Assets (in million RMB)	28.3	4.5	20.2	30.1	4.7	9.2
	(35.7)	(5.3)	(56.0)	(37.4)	(4.6)	(8.5)
Employment	1565	264	425	1708	308	436
	(1858)	(299)	(502)	(1984)	(340)	(502)
Physical Capital Intensity						
Fixed Productive Assets Per Worker (in 1,000 RMB)	22.7	23.2	61.9	21.0	20.7	34.9
	(20.5)	(24.9)	(83.6)	(16.9)	(15.2)	(34.2)
Human Capital (%)						
Junior High-School or Below	43	59	40	42	59	43
	(20)	(27)	(23)	(20)	(26)	(26)
Senior High-School	35	27	28	36	27	31
	(17)	(17)	(16)	(17)	(17)	(17)
College or Above	23	15	32	23	14	27
	(10)	(12)	(21)	(10)	(11)	(20)
Firm Profitability						
Profits Per Fixed Productive Assets	0.4	0.5	0.6	0.4	0.5	0.7
	(0.4)	(0.4)	(0.5)	(0.4)	(0.4)	(0.5)
Profits Per Worker (in 1,000 RMB)	8.1	10.6	27.0	7.5	11.1	22.5
	(10.6)	(12.0)	(29.7)	(7.8)	(13.3)	(35.2)
Number of Firms	124	74	50	103	50	16

Notes: The smaller sample includes the firms which have information on firm employment, fixed assets, profits and output prior to the technology project. Firm size, physical capital intensity, and firm profitability are for 1993. Human capital is for 1994. The exchange rate is RMB 8.28 per $US. Standard deviations are in parentheses.

Table 3. Summary Statistics on Technology Projects

	State-owned Firms		Collectively-owned Firms		Joint Ventures	
	mean	>0[a]	mean	>0[a]	mean	>0[a]
Project Size						
Absolute size (in million RMB)	10.5		1.9		3.1	
	(20.8)		(2.4)		(4.6)	
Project size relative to fixed productive assets[b] (%)	31		50		41	
Project Expenditure Breakdown[c] (%)						
Imported equipment	35	75	21	42	42	63
	(32)		(30)		(43)	
Domestic equipment	30	75	36	80	37	56
	(29)		(30)		(40)	
Construction of new facility	15	60	16	56	7	31
	(19)		(21)		(13)	
Prototype development	13	60	20	70	11	38
	(20)		(24)		(23)	
Sources of Project Financing[c] (%)						
Bank loans	46	84	29	63	36	50
	(32)		(31)		(44)	
Internal funds	43	92	61	98	43	81
	(31)		(34)		(40)	
Foreign investment	4	8	3	4	20	31
	(14)		(14)		(34)	
Project Performance[d]						
Project gross profits relative to project size	0.96		0.98		1.23	
	(1.56)		(1.29)		(1.90)	
Project capacity utilization rate (%)	85.07		87.31		85.63	
	(16.07)		(11.44)		(16.86)	
Number of Firms	103		50		16	

Notes: This table reports summary statistics for the smaller sample that includes firms with information on firm employment, fixed assets, profits and output prior to the technology project. Standard deviations are in parentheses. The exchange rate is RMB 8.28 per $US.

a) In the column of '>0', we report the percentage of firms for which the variable is greater than zero. For example, for collectively-owned firms, '42' in the row of 'imported equipment' indicates that 42 percent of collectively-owned firms invested in imported equipment.

b) The median values are reported.

c) Project expenditure also includes training and one-time technology transfer fees. Sources of project financing also come from equipment suppliers and others. Since these items are very small, they are not reported in the table.

d) Project profits and capacity utilization rates are for 1993.

Table 4. Project Size

					Benchmark	
	(1)	(2)	(3)	(4)	(5)	(6)
State-owned Firm	0.86	-0.26	-0.29	-0.29	-0.32	-0.47
	(2.97)	(-0.94)	(-0.96)	(-0.97)	(-1.05)	(-1.60)
Joint Venture	0.44	-0.14	-0.25	-0.25	-0.38	-0.56
	(1.03)	(-0.43)	(-0.71)	(-0.72)	(-1.10)	(-1.55)
Bank Loan*State-owned Firm					1.38	1.68
					(2.52)	(4.36)
Bank Loan*Collectively-owned Firm					0.40	0.07
					(0.54)	(0.18)
Bank Loan*Joint Venture					-1.50	-1.05
					(-2.45)	(-1.90)
Log(Firm Profits / Fixed Assets)$_0$				0.03	0.02	-0.09
				(0.28)	(0.18)	(-0.89)
Log(Firm Fixed Assets)$_0$		0.30	0.49	0.52	0.53	0.44
		(1.91)	(2.55)	(2.17)	(2.27)	(1.95)
Log(Firm Output)$_0$		0.32	0.33	0.31	0.28	0.42
		(2.08)	(2.07)	(1.64)	(1.55)	(2.48)
Log(Firm Employment)$_0$		0.21				
		(1.18)				
Log(Firm Fixed Assets / Employment)$_0$			-0.25	-0.25	-0.26	-0.29
			(-1.30)	(-1.29)	(-1.36)	(-1.59)
% of Senior High-school Graduates			0.00	0.00	-0.00	-0.00
			(0.06)	(0.01)	(-0.50)	(-0.15)
% of College Graduates			0.01	0.01	0.01	0.01
			(0.47)	(0.45)	(0.68)	(0.62)
Firm Established in the Period 1978-89			-0.08	-0.09	-0.01	0.01
			(-0.28)	(-0.30)	(-0.02)	(0.02)
Firm Established in the 1990s			0.14	0.14	0.32	0.37
			(0.38)	(0.36)	(0.90)	(1.04)
R^2	0.19	0.47	0.47	0.47	0.52	0.55

Notes: This table reports estimates of equation (5). The dependent variable is the logarithm of project expenditure. All specifications include controls for firm sector and the year when the technology project started. There are 169 observations. The omitted category for ownership is collectively-owned firms. 'Bank loan' in column 5 is the fraction of project expenditure that is financed through bank loans, while in column 6 it is a dummy variable which equals 1 if the firm used bank loans to finance the project. Firm profits, fixed assets, output and employment are prior to the project. '% of senior high-school graduates' and '% of college graduates' represent the percentage of workers who have senior high-school diploma and college degree or above, respectively. The data on worker's education are for 1994. The omitted category is workers with a junior high-school diploma or below. The omitted category for firm age is firms which established before 1978. In parentheses are t-statistics. Standard errors are robust to heteroscedasticity.

Table 5. Investment in Imported Equipment versus Domestic Equipment

	OLS[a]		Tobit[b]			Probit[c]	OLS[d]
	imported	domestic	imported	domestic	imported	imported=1	imported>0
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
State-owned Firm	0.43	-0.51	0.59	-0.79	0.05	0.33	-0.40
	(0.86)	(-1.10)	(0.77)	(-1.62)	(0.50)	(0.97)	(-0.84)
Joint Venture	-0.28	-0.31	-0.27	-0.73	0.02	-0.26	-0.21
	(-0.37)	(-0.44)	(-0.24)	(-0.75)	(0.14)	(-0.53)	(-0.39)
Bank Loan*State-owned Firm	2.13	0.07	2.23	-0.22	0.17	0.38	2.08
	(2.99)	(0.10)	(2.33)	(-0.21)	(1.30)	(0.82)	(3.31)
Bank Loan*Collectively-owned Firm	0.20	-0.28	0.66	-0.06	0.21	-0.20	1.49
	(0.19)	(-0.26)	(0.36)	(-0.04)	(0.93)	(-0.30)	(1.21)
Bank Loan*Joint Venture	-2.23	1.83	-3.04	2.87	-0.37	-0.68	-1.85
	(-1.56)	(1.38)	(-1.39)	(1.60)	(-1.09)	(-0.70)	(-1.62)
Log(Firm Profits / Fixed Assets)$_0$	0.42	0.07	0.62	0.12	0.07	0.31	0.08
	(2.34)	(0.43)	(2.37)	(0.56)	(2.32)	(2.60)	(0.56)
Log(Firm Fixed Assets)$_0$	0.95	0.60	1.53	0.69	0.10	0.56	0.58
	(2.58)	(1.76)	(2.64)	(1.72)	(1.32)	(2.18)	(1.98)
Log(Firm Output)$_0$	-0.05	0.12	-0.24	0.15	-0.01	-0.14	0.07
	(-0.16)	(0.44)	(-0.52)	(0.49)	(-0.18)	(-0.65)	(0.30)
Log(Firm Fixed Assets / Employment)$_0$	-0.01	-0.73	0.11	-0.98	0.14	0.06	0.05
	(-0.04)	(-2.43)	(0.29)	(-2.62)	(2.47)	(0.31)	(0.18)
% of Senior High-school Graduates	-0.00	0.01	0.00	0.01	0.00	0.00	-0.00
	(-0.30)	(0.74)	(0.04)	(1.17)	(0.01)	(0.12)	(-0.01)
% of College Graduates	0.01	-0.00	0.03	-0.01	0.00	0.02	-0.01
	(0.78)	(-0.22)	(1.13)	(-0.42)	(1.58)	(1.33)	(-0.65)
Firm Established in the Period 1978-89	-0.35	-0.15	-0.56	-0.22	-0.10	-0.28	0.17
	(-0.72)	(-0.30)	(-0.82)	(-0.39)	(-1.13)	(-0.88)	(0.39)
Firm Established in the 1990s	0.53	0.13	0.79	0.01	0.02	0.29	0.18
	(0.90)	(0.21)	(0.95)	(0.01)	(0.14)	(0.68)	(0.35)
Number of Observations	169	169	169	169	169	169	108
R^2	0.45	0.31					0.51
Log Likelihood			-309.90	-334.20	-88.95	-75.64	

Notes: This table examines investment in imported and domestic equipment. All specifications include controls for firm age, sector and the year when the technology project started. In parentheses are t-statistics. Standard errors are robust to heteroscedasticity. See the notes to Table 4 for more detail about other variables.

a) The dependent variables in columns 1-2 are the logarithm of expenditure on imported equipment plus 1, and the logarithm of expenditure on domestic equipment plus 1, respectively.

b) Columns 3-5 report the left-censored Tobit estimates. 61 firms did not import equipment and 43 firms did not purchase domestic equipment. The dependent variables in columns 3-4 are the same as those in columns 1-2 correspondingly. The dependent variable in column 5 is the share of expenditure on imported equipment.

c) The dependent variable is a dummy variable which equals 1 when the firm imported equipment, and 0 otherwise.

d) Column 7 excludes firms which did not import equipment. The dependent variable is the logarithm of expenditure on imported equipment plus 1.

Table 6. Project Profitability

	Pooled OLS		Random-Effects		Hausman-Taylor	
	(1)	(2)	(3)	(4)	(5)	(6)
State-owned Firm	0.11	0.15	0.06	0.01	0.12	0.91
	(-0.32)	(0.43)	(0.16)	(0.03)	(0.13)	(0.50)
Joint Venture	-0.28	-0.35	-0.44	-0.50	0.02	1.66
	(-0.50)	(-0.67)	(-0.83)	(-0.96)	(0.02)	(0.49)
Bank Loan*State-owned Firm	-2.30	-2.50	-2.31	-2.51	-3.41	3.38
	(-3.56)	(-3.73)	(-4.30)	(4.67)	(-0.43)	(0.21)
Bank Loan*Collectively-owned Firm	-0.22	-0.21	-0.18	-0.21	4.93	6.95
	(-0.33)	(-0.31)	(-0.22)	(-0.26)	(1.05)	(0.84)
Bank Loan*Joint Venture	0.94	1.06	0.58	0.81	13.22	23.73
	(0.76)	(0.92)	(0.54)	(0.75)	(1.00)	(0.92)
Log(Firm Profits / Fixed Assets)$_0$	0.20	0.16	0.19	0.16	0.12	-0.20
	(1.51)	(1.23)	(1.45)	(1.17)	(0.12)	(-0.11)
Log(Firm Fixed Assets)$_0$	-0.01	-0.03	-0.15	-0.18	-0.79	-1.52
	(-0.04)	(-0.13)	(-0.56)	(-0.66)	(-0.75)	(-0.76)
Log(Firm Output)$_0$	-0.18	-0.18	-0.14	-0.15	0.00	-0.00
	(-0.95)	(-0.95)	(-0.68)	(-0.72)	(0.13)	(-0.08)
Log(Firm Fixed Assets / Employment)$_0$	0.48	0.40	0.57	0.46	1.74	3.38
	(1.91)	(1.56)	(2.49)	(2.00)	(1.29)	(1.09)
2nd Year of Project	0.33	0.32	0.28	0.28	0.27	0.23
	(3.97)	(3.91)	(3.54)	(3.55)	(1.79)	(1.30)
3rd Year of Project	0.44	0.44	0.43	0.43	0.38	0.30
	(1.91)	(1.92)	(2.63)	(2.66)	(1.36)	(0.89)
4th Year of Project	0.49	0.48	0.55	0.55	0.46	0.35
	(1.58)	(1.52)	(2.33)	(2.35)	(1.11)	(0.69)
5th Year of Project	1.24	1.24	0.91	0.92	0.75	0.57
	(2.99)	(3.05)	(2.68)	(2.72)	(1.21)	(0.76)
Expenditure Share of Imported Equipment		0.77		0.97		-6.64
		(1.37)		(2.14)		(-0.78)
R^2	0.24	0.27	0.23	0.26		
Wald χ^2					180.10	145.10

Notes: This table reports the estimates of equation (6). The dependent variable is the logarithm of project gross profits relative to project size. All specifications include controls for human capital, firm age, sector and year. '2nd year of project' is a dummy variable which equals to 1 if the data are for a project in its 2nd year. The omitted category for the duration of project is the project's 1st year. See the notes to Table 4 for more detail about other variables. There are 398 observations. *t*-statistics are in parentheses. In columns 1-2, standard errors are robust to heteroscedasticity and serial correlation.

Table 7. Project Capacity Utilization

	Pooled OLS		Random-Effects		Hausman-Taylor	
	(1)	(2)	(3)	(4)	(5)	(6)
State-owned Firm	-0.18	-0.18	-0.17	-0.17	-0.39	-0.40
	(-2.86)	(-2.92)	(-3.01)	(-3.01)	(-0.75)	(-0.76)
Joint Venture	-0.09	-0.10	-0.07	-0.09	-0.49	-0.54
	(-0.76)	(-0.85)	(-0.88)	(-1.06)	(-0.39)	(-0.41)
Bank Loan*State-owned Firm	-0.26	-0.28	-0.20	-0.21	-1.79	-1.50
	(-2.10)	(-2.33)	(-2.33)	(-2.51)	(-0.29)	(-0.23)
Bank Loan*Collectively-owned Firm	-0.01	-0.00	0.02	0.03	0.66	0.63
	(-0.14)	(-0.04)	(0.17)	(0.23)	(0.27)	(0.26)
Bank Loan*Joint Venture	0.10	0.13	0.07	0.10	-0.18	-0.27
	(0.50)	(0.58)	(0.38)	(0.59)	(-0.04)	(-0.06)
Log(Firm Profits / Fixed Assets)$_0$	0.04	0.04	0.03	0.03	0.19	0.13
	(1.66)	(1.34)	(1.52)	(1.21)	(0.20)	(0.12)
Log(Firm Fixed Assets)$_0$	0.14	0.13	0.10	0.09	0.27	0.24
	(1.94)	(1.66)	(2.25)	(2.04)	(0.31)	(0.27)
Log(Firm Output)$_0$	-0.09	-0.08	-0.06	-0.05	0.00	0.00
	(-1.64)	(-1.44)	(-1.68)	(-1.54)	(0.58)	(0.62)
Log(Firm Fixed Assets / Employment)$_0$	-0.01	-0.02	-0.01	-0.02	0.05	0.03
	(-0.33)	(-0.52)	(-0.19)	(-0.41)	(0.04)	(0.03)
2nd Year of Project	0.07	0.07	0.07	0.07	0.11	0.11
	(3.23)	(3.23)	(3.59)	(3.59)	(2.82)	(2.86)
3rd Year of Project	0.09	0.09	0.12	0.12	0.21	0.21
	(2.54)	(2.63)	(3.20)	(3.20)	(2.82)	(2.86)
4th Year of Project	0.11	0.11	0.13	0.13	0.26	0.26
	(2.15)	(2.15)	(2.58)	(2.57)	(2.36)	(2.40)
5th Year of Project	0.19	0.19	0.16	0.16	0.34	0.35
	(3.75)	(3.69)	(2.35)	(2.35)	(2.06)	(2.10)
Expenditure Share of Imported Equipment		0.08		0.10		0.42
		(0.85)		(1.35)		(0.21)
R^2	0.29	0.30	0.28	0.29		
Wald χ^2					137.32	141.67

Notes: This table examines project capacity utilization. The dependent variable is the logarithm of project capacity utilization rates. All specifications include controls for human capital, firm age, sector and year. See the notes to Tables 4 and 6 for more detail about other variables. There are 346 observations. t-statistics are in parentheses. In columns 1-2 standard errors are robust to heteroscedasticity and serial correlation.