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# Trade, technology, and China's rising skill demand[1]

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## Abstract

China has experienced rising wage inequality due to rising relative demand for skilled labour. In this paper, we use a sample of 1,500 firms to investigate the impact of trade and technology on China's rising skill demand. We find that export expansion had a negative direct effect (Heckscher–Ohlin type) and a positive indirect effect (export-induced skill-biased technical change) on skill demand; the net effect was found positive and accounted for 5 percent of rising skill demand of the sample firms. We find that technical change in Chinese firms was on average skill-neutral, but majority foreign-owned firms experienced skill-biased technical progress that accounted for 22 percent of the rising skill demand of the sample firms.

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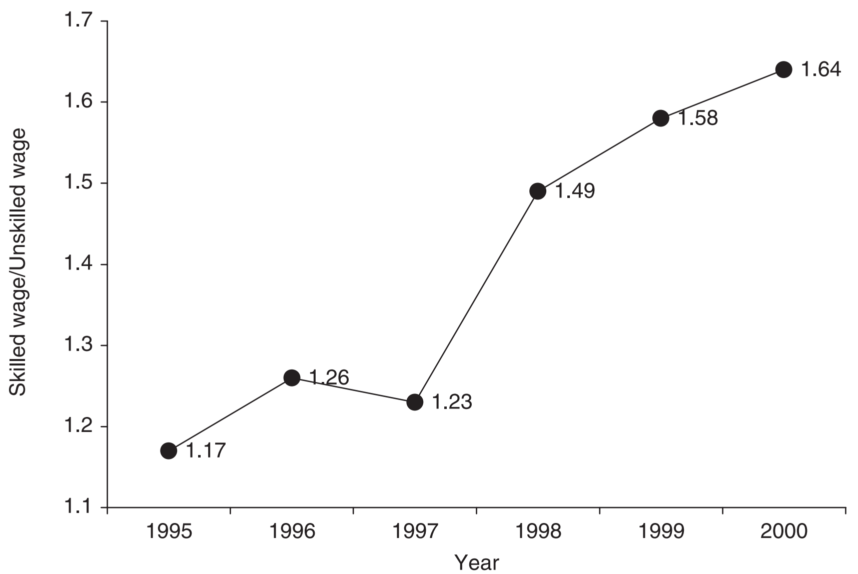
## 1. Introduction

The past two decades have seen China experiencing rapid growth in national income, export volume and foreign direct investment.[2] This rapid economic growth has been accompanied, however, by rising income inequality. According to Chinese official statistics cited by Chang (2002), the Gini coefficient (a measure of income inequality) of China rose from a low level of 0.33 in 1980 to 0.40 in 1994, and to 0.46 in 2000. China's current inequality level is higher than that of India (0.38) and Ethiopia (0.40). More alarmingly, China's income inequality grew at an average of 2 percent per year in the 1980s and 2.5 percent per year in the 1990s, one of the fastest rates of growth of inequality in the world.

One important component of income inequality is wage inequality. Khan and Riskin (1998) estimated, based on surveys of Chinese urban households, that the contribution of wage inequality to total income inequality in China was about one third in 1988 and a half in 1995. In Figure 1, we show China's wage inequality measured by the ratio of the average wage of skilled workers to the average wage

**Figure 1. China's wage inequality, 1995–2000**




[2] For a survey of the modern Chinese economy, see Chow (2002).

of unskilled workers for the period 1995–2000.[3] According to this measure, China's wage inequality rose by an average of 11 percent per year from 1997 to 2000.

It is clear that this sharp rise in China's wage inequality was not due to supply-side factors. During this period, China's supply of skilled labour relative to unskilled labour increased rather than decreased. For China's wage inequality to rise, the relative demand for skilled labour must have increased more than the relative supply. Thus, to investigate the reasons for China's rising wage inequality, we examine the reasons for China's rising demand for skilled labour.

In this paper, we use firm-level survey data to investigate the causes of rising demand for skilled labour in China in the period 1998–2000. Our data come from a survey by the World Bank of 1,500 firms in five major cities in China: Beijing, Chengdu, Guangzhou, Shanghai and Tianjin.[4] The survey contains information on each firm's legal status, ownership share, export status, industry affiliation, domestic and foreign sales, capital assets, and R&D expenditures. Important to our research, the survey distinguishes between skilled workers and unskilled workers, which allows us to construct a variable that measures the relative demand for skilled labour.

The methodology of our study follows the recent literature on globalization and wage inequality. Rising wage inequality has been observed in many countries in the past two decades.[5] In examining the causes of rising wage inequality in industrial countries, in particular the US, researchers have identified two main candidates. The first one is skill-biased technical progress that increases the demand for skilled workers relative to unskilled workers. For example, Feenstra and Hanson (1999) find that the adoption of computer technology in the workplace accounts for 20–35 percent of the increase in relative demand for non-production workers (a proxy for skilled workers) in the US over the period 1979–1990. The second cause is globalization defined as increasing international trade and investment. In the Heckscher–Ohlin trade model and the Feenstra–Hanson (1996) outsourcing model, openness in trade and investment is shown to make industrial countries more specialized in skill-intensive production and hence raise the relative demand for skilled labour. Feenstra and Hanson (1999) find that trade and outsourcing activities by US multinational enterprises account for 15–25 percent of the increase in relative demand for non-production workers in the US over the period 1979–1990.

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[3] Based on sample survey data published in *China Labour Statistical Yearbook*. Skilled workers are defined as those with education at college level and above. Unskilled workers are defined as those with junior middle school education and below.

[4] Beijing is the capital of China and also an industrial and commercial centre in north China. Chengdu is an industrial and commercial centre in middle China, Guangzhou is an industrial and commercial centre in south China, Shanghai is an industrial and commercial centre in east China and Tianjin is a major industrial city in northeast China.

[5] Berman, Bound and Machin (1998, figure 4) report information on wage inequality in 16 developed countries and 8 less developed countries in the 1980s, out of which 17 experienced rising wage inequality. See also Robbins (1996) and Wood (1994, 1997) for evidence of rising wage inequality in less developed countries.

Technology and globalization also play key roles in explaining rising skill demand in developing countries. While the Heckscher–Ohlin model predicts that trade opening will decrease wage inequality in developing countries because it raises the relative price of unskilled-intensive goods and hence the relative demand for unskilled labour, newly-developed trade models (Davis, 1996; Trefler and Zhu, 2001; Xu, 2003) show that trade opening can be a cause for rising wage inequality in developing countries as well. Moreover, diffusion of skill-biased technologies from industrial countries to developing countries constitutes another cause of rising wage inequality in developing countries (Acemoglu, 1998; Wood, 1994), and international trade and investment are important channels for such technology diffusion.

There are several recent studies on rises in wage inequality in developing countries. Most of the studies identify skill-biased technical change to be the main reason and link such change to foreign direct investment and imports of technology-intensive goods. For example, Alvarez and Robertson (2004) use firm-level data to examine the relationship between exposure to foreign markets and technology innovations in Chile and Mexico, and find evidence of a positive relationship which is stronger in the period after trade and investment liberalization. Mazumdar and Quispe-Agnoli (2002) find evidence of skill-biased technical change responsible for rising wage inequality in Peru following its trade liberalization in the early 1990s. They identify the channel as skill-biased technology embodied in imported machinery. Robbins and Gindling (1999) present evidence that trade liberalization in Costa Rica, by inducing an acceleration of physical capital imports, led to an increase in relative skill demand. Using plant-level data from Chile, Pavcnik (2003) examines whether capital and investment, the use of imported materials, foreign technical assistance and patented technology affect the relative demand for skilled workers and finds positive evidence.[6] Several other studies examine the direct effect of trade liberalization rather than the trade-induced technology effect. For example, Hanson and Harrison (1999) find that the 1985 trade reform in Mexico disproportionately affected low-skilled industries and interpret this as being caused by increased competition from economies such as China with reserves of cheap unskilled labour larger than Mexico's. Kim (2002) finds a positive effect on Korea's wage inequality from trade expansion with less advanced trade partners and a negative effect from trade expansion with more advanced trade partners, consistent with the standard Heckscher–Ohlin model prediction.

Despite the fact that China has experienced a sharp increase in wage inequality, there has been little investigation into its causes (with a few exceptions discussed below). One reason is that China, while moving towards a market economy, still has the significant presence of a government-controlled economic segment. Such institutional characteristics may have significant effects on wage inequality. Zhao (2001), using

[6] See also Feenstra and Hanson (1997) on the role of Maquiladoras in raising Mexico's wage inequality, Harrison and Hanson (1999) on a study of rising wage inequality in Mexico after the 1985 trade reform, and Beyer, Rojas and Vergara (1999) on evidence of a positive correlation between trade openness and wage inequality in Chile.

Chinese urban household survey data, investigates the effects of foreign direct investment on wage inequality associated with segmented labour markets and high labour mobility costs. She finds that less educated workers earn significantly less in foreign-invested enterprises than in state-owned enterprises but more educated workers earn more in the former than in the latter. This asymmetry implies that the mere entry of foreign firms can raise wage inequality in the absence of skill-biased technical change. Such implications suggest that a study of China's wage inequality must consider the nature of firm ownership in addition to technology and openness in trade and investment. Wu (2001) presents a theoretical model and some empirical evidence that shows that the relative wage of skilled workers in China increases as China opens up its market more and attracts foreign direct investment more into high-tech sectors. She shows further that the degree of intellectual property rights protection inversely affects the size of the rise in wage inequality.

Our paper applies an empirical method that has been widely used in recent studies of skill demand and wage inequality. The method, first adopted by Berman, Bound and Griliches (1994), derives a regression equation from the short-run cost function that links the wage-bill share of skilled workers and determinants of skilled labour demand (details in Section 2). Feenstra and Hanson (1999) use this regression equation in their investigation of rising demand for non-production workers in the US, while Hsieh and Woo (2005) use it to examine the rising demand for skilled workers in Hong Kong due to outsourcing of unskilled-labour activities to mainland China. To our knowledge, this method has not been applied before to the study of China's rising skill demand. Data availability may be one of the reasons that such a study has not been implemented, and lack of an empirical approach that utilizes existing data may be another. In this paper, we develop an approach that allows us to use the World Bank firm survey data in the aforementioned regression framework. Our empirical analysis provides an estimation of firm-level variation in relative demand for skilled workers in China, linking it to variations in firm ownership, export intensity, technology intensity and foreign direct investment. The results from this empirical analysis provide a useful indication of the main forces behind China's rising wage inequality.

The remainder of the paper is organized as follows. In Section 2, we derive the benchmark regression equation from a short-run cost function and explain the structural variables included in the equation and the theories behind them. In Section 3, we provide a description of the data and the variables used in our regression implementation. In Section 4, we report our main results and offer our interpretation of them. In Section 5, we summarize our conclusions.

## 2. The model

Consider a three-factor model of production. The three factors are unskilled labour, skilled labour and capital. Assuming a neoclassical production function, the output of firm $n$ equals $Y_n = G_n(L_n, H_n, K_n, \mathbf{Z}_n)$, where $L_n$, $H_n$ and $K_n$ are unskilled labour, skilled labour and capital employed by firm $n$, and $\mathbf{Z}_n$ is a vector of structural variables that shift the production function (for example, technology, firm ownership and commodity prices). Let $w_L$, $w_H$ and $r$ denote unskilled wage rate, skilled wage rate and rental rate of capital, respectively. Firm $n$'s short-run cost function, obtained when it treats the levels of capital and output as fixed in its labour employment decision, is given by:

$$C_n(w_L, w_H, K_n, Y_n, \mathbf{Z}_n) = \min_{L_n, H_n}[w_L L_n + w_H H_n] \text{ subject to } Y_n = G_n(L_n, H_n, K_n, \mathbf{Z}_n). \quad (1)$$

This cost function links the short-run labour cost to wages, capital stock, output and structural variables.

To obtain an equation for empirical estimation, we apply a second-order Taylor approximation in logarithms to Equation (1). Defining $w_i \equiv (w_1, w_2)$ and $x_k \equiv (K_n, Y_n, \mathbf{Z}_n)$, we obtain from the Taylor approximation the following translog cost function:

$$\begin{aligned} \ln C_n = \alpha_0^n &+ \sum_{i=1}^{m} \alpha_i^n \ln w_i + \sum_{k=1}^{\kappa} \beta_k^n \ln x_k + \frac{1}{2}\sum_{i=1}^{m}\sum_{j=1}^{m} \gamma_{ij}^n \ln w_i \ln w_j \\ &+ \frac{1}{2}\sum_{k=1}^{\kappa}\sum_{l=1}^{\kappa} \delta_{kl}^n \ln x_k \ln x_l + \sum_{i=1}^{m}\sum_{k=1}^{\kappa} \phi_{ik}^n \ln w_i \ln x_k \end{aligned} \quad (2)$$

where $m$ is the number of inputs optimally chosen to minimize labour cost and $\kappa$ is the number of predetermined variables (that is, fixed inputs, output and structural variables). Differentiating Equation (2) with respect to $\ln w_i$ yields a system of cost-share equations:

$$s_{ni} = \alpha_i^n + \sum_{j=1}^{m} \gamma_{ij}^n \ln w_j + \sum_{k=1}^{\kappa} \phi_{ik}^n \ln x_k. \quad (3)$$

In Equation system (3), $s_{ni} \equiv \partial \ln C_n / \partial \ln w_i = w_i L_{ni} / C_n$ is the cost share of factor $i$, where $L_{ni}$ denotes the optimally chosen employment level of factor $i$ in firm $n$.[7]

In our three-factor model, a firm minimizes total production cost by choosing the employment amount of unskilled labour ($L$) and skilled labour ($H$). In this case, Equation (3) contains two cost-share equations. By definition, $s_{nL} + s_{nH} = 1$, so one of the two cost-share equations is redundant.[8] In our estimation, we use the cost-share

[7] In specifying the translog cost function, we impose the symmetric requirement of $\gamma_{ij} = \gamma_{ji}$. For the translog cost function to be homogeneous of degree one in wages, parameters must meet the restrictions of $\sum_{i=1}^{m} \alpha_i^n = 1$ and $\sum_{j=1}^{m} \gamma_{ij}^n = 0$.

[8] Since one cost-share equation can be derived from the other, $\sum_{i=1}^{m} \alpha_i^n = 1$ is satisfied.

equation for skilled labour, $s_{nH}$. From Equation (3), we see that $s_{nH}$ depends on the wage rates paid to both types of labour, as well as capital stock, output and structural variables. When estimating the cost-share equation by pooling data across firms, researchers often argue that cross-firm variations in the wage rates contain little information: wage rates differ across firms principally due to quality variation in the workers employed by different firms, so we do not expect high-wage firms to economize on these high-quality workers. Accordingly, the wage terms in Equation (3) are generally included in the constant term or in the fixed effects when pooling data across firms.[9] This leaves just fixed capital, output and other structural variables as explanatory variables. Taking the difference between two years to sweep out firm-specific fixed effects, we obtain the following skilled-wage-share-change equation:

$$\Delta s_{nH} = \phi_0 + \phi_K \,\Delta \ln K_n + \phi_Y \,\Delta \ln Y_n + \phi_Z' \,\Delta \mathbf{Z}_n. \tag{4}$$

In our estimation, we assume that $\phi_0$ differs across industries and cities, and the coefficients on explanatory variables are constant across firms.

Three structural variables are expected to affect the change in cost share of skilled labour. The first structural variable is the rate of technical progress, measured by the change in the ratio of R&D stock to output, $\Delta(T_n/Y_n)$. The second structural variable is the change in export intensity, measured by the change in the ratio of export sales to output, $\Delta(X_n/Y_n)$. The third structural variable is firm ownership. In the context of the Chinese economy, the nature of firm ownership is likely to be important for changes in wage and employment structure. Incorporating these considerations yields the following regression equation:

$$\begin{aligned} \Delta s_{nH} = {} & \beta_i + \beta_c + \beta_1 \,\Delta \ln (K_n/Y_n) + \beta_2 \,\Delta \ln Y_n + \beta_3 \,\Delta(T_n/Y_n) \\ & + \beta_4 \,\Delta(X_n/Y_n) + \beta_5 D_n^s + \beta_6 D_n^f + \varepsilon_n. \end{aligned} \tag{5}$$

In this equation, $\beta_i$ captures industry-specific fixed effects, $\beta_c$ captures city-specific fixed effects and $\varepsilon_n$ is assumed to be a zero-mean error term that captures the remaining unobserved effects. The set of explanatory variables includes $\Delta \ln (K_n/Y_n)$ (change in capital intensity), $\Delta \ln Y_n$ (change in firm size), $\Delta(T_n/Y_n)$ (change in technology intensity), $\Delta(X_n/Y_n)$ (change in export intensity) and two ownership dummy variables. $D_n^s = 1$, if firm $n$ is state-owned and 0 otherwise. $D_n^f = 1$, if firm $n$ is foreign-owned and 0 otherwise.

The cost function approach is useful in yielding a linear estimation equation. Including structural variables in the cost function implies that it is treated as a reduced-form equation from a structural model. How structural variables affect

[9] This approach follows Berman, Bound and Griliches (1994) and our explanation of this approach comes from Feenstra (2004, chapter 4). Having excluded wage rates from the set of explanatory variables, we do not need to impose the parameter restriction $\sum_{j=1}^{m} \gamma_{ij}^n = 0$ in our estimation.

wages depends on the underlying structural model. While we do not attempt to develop such a model, we provide below a discussion of the expected signs of $\beta_1$ to $\beta_6$ based on existing economic theories.

We first note that the cost share of skilled labour, $s_{nH} \equiv w_H H_n/(w_L L_n + w_H H_n)$, corresponds to the relative demand for skilled labour in the firm. Given relative supply of skilled labour, an increase in relative demand of skilled labour raises $H_n/L_n$ at the given market rate of relative wage, $w_H/w_L$. Aggregating relative skill demand for all firms implies an increase in the relative skill demand of the economy, which in turn implies an increase in the equilibrium market rate of relative wage of skilled workers. Thus an estimation of the determinants of the change in skilled wage share in Equation (5) allows an identification of the determinants of the change in wage inequality.

The coefficient $\beta_1$ captures the effect of capital $\Delta(K_n/Y_n)$, depending on the change in relative skill demand. If $\beta_1 > 0$, then capital complements technology. There is ample evidence that capital complements skill in the modern economy and recent studies provide further confirmation of this capital–skill complementarity (for instance, Feenstra and Hanson, 1999). The coefficient $\beta_2$ captures the effect of firm expansion ($\Delta Y_n$). Many empirical studies have found that the relative demand for skilled labour increases as a firm expands its size, and therefore $\beta_2 > 0$ is expected.

The coefficient $\beta_3$ captures the effect of technical change, $\Delta(T_n/Y_n)$, on the change in relative skill demand. The sign of $\beta_3$ can be positive, zero or negative, reflecting the factor bias of the technical change. For example, if $\beta_3 > 0$, it implies that firms adopt technologies that complement skilled workers, referred to as skill-biased technical change in the literature. $\beta_3 = 0$ indicates factor-neutral technical change. If $\beta_3 < 0$, it is evidence of technical change biased towards unskilled workers.[10] A recent literature on endogenous technology bias (including Acemoglu, 1998) argues that a high skill intensity tends to induce firms to adopt skill-biased technologies and a low skill intensity tends to induce firms to adopt technologies biased towards unskilled labour. We shall examine this theoretical prediction in our empirical estimation.

The coefficient $\beta_4$ shows the effect of change in export intensity, $\Delta(X_n/Y_n)$, on relative skill demand. If exported goods are relatively unskilled-intensive, then $\beta_4 < 0$. This is the prediction of the standard Heckscher–Ohlin trade model for an unskilled-labour-abundant country like China. However, if exported goods are relatively skill-intensive, then $\beta_4 > 0$. Recent models such as Feenstra and Hanson (1996) show that an unskilled-labour-abundant country, with multinational subsidiaries located there, may export goods that are skill-intensive (relative to the other goods that the country produces) rather than unskilled-intensive. It is thus interesting to see for the Chinese economy if the estimated sign of $\beta_4$ supports the

[10] See Xu (2001) for a theoretical analysis of the relations between relative skill demand and biased technical changes in an open economy.

Heckscher–Ohlin prediction or the prediction of some new trade models, and also see if the estimated signs of $\beta_4$ differ between domestic and foreign firms in China.

The dummy variable for state-owned firms ($D_n^s$) and that for foreign-owned firms ($D_n^f$) are intended to examine if state ownership and foreign ownership have distinctive effects on the change in relative demand for skilled workers. The study by Zhao (2001), discussed in the introduction, finds that skilled workers earn significantly more in foreign firms than in state firms while unskilled workers own significantly less in foreign firms than in state firms. This would imply that $\beta_5 < 0$ and $\beta_6 > 0$.[11]

It is worth noting that our regression equation is derived from a short-run cost function which assumes that firms treat capital $K_n$ and output $Y_n$ as fixed in making their employment decisions. In the dynamic Chinese economy, firms are likely to treat capital and output as variables in their employment decisions. The main reason that we choose the short-term cost function approach is that estimation of a long-term cost function would require data on product prices (Feenstra and Hanson, 1999), which are not available for us. It is therefore important to bear in mind when interpreting our results that the estimated effects of capital deepening ($\Delta(K_n/Y_n)$) and output expansion ($\Delta Y_n$) may be partly reflecting the effects of changes in structural variables. For example, if the estimated effect of output expansion is positive, part of it may be a result of export expansion (that is, as a firm expands its exports, its production and sales scale expands, which may be estimated as an effect of $\Delta Y_n$).

## 3. Data

Our investigation uses data from a World Bank survey of 1,500 firms in five cities in China for the period 1998–2000.[12] The five cities, Beijing, Chengdu, Guangzhou, Shanghai and Tianjin, are all important production centres in China. The sample contains 300 firms in each city.

Table 1 reports sample distribution by ownership, export status, industry and city. The survey contains two sets of questions about a firm's ownership. First, a firm reports its legal status in 10 categories and may report multiple categories. Second, a firm provides information on ownership shares. Based on legal status, 21.5 percent of the 1,500 firms are state-owned firms, 15.8 percent are cooperatively

[11] Separating state firms from the sample is necessary because their operation is fundamentally different from market-oriented firms. For example, state firms in China have an incentive to keep government subsidies for unskilled labour employment, which may induce them to artificially hire more unskilled workers and pay less to skilled workers. In this case the observed rise in relative skill demand does not correspond to higher wage inequality. For an analysis of China's government regulation and its implications, see Gordon and Li (2003).

[12] We thank the World Bank and the Davidson Data Center and Network (DDCN) for providing the data.

**Table 1. Sample distribution by ownership, export status, industry and city**

| | Number | Share (%) |
|---|---|---|
| Legal status | | |
| State-owned | 323 | 21.53 |
| Cooperative/collective | 237 | 15.80 |
| Foreign joint venture | 181 | 12.07 |
| Foreign subsidiary | 40 | 2.67 |
| Others[a] | 719 | 47.93 |
| Ownership share | | |
| Wholly state-owned | 262 | 17.47 |
| Wholly domestic non-state owned[b] | 626 | 41.73 |
| Majority foreign-owned | 449 | 29.93 |
| Minority foreign-owned | 99 | 6.60 |
| Ownership not reported | 60 | 4.27 |
| Export status | | |
| Exporting in 1998 | 381 | 25.40 |
| Exporting in 2000 | 457 | 30.47 |
| Non-exporting in 1998 | 1,119 | 74.60 |
| Non-exporting in 2000 | 1,043 | 69.53 |
| Industry[c] | | |
| Apparel and leather goods | 222 | 14.80 |
| Vehicles and vehicle parts | 216 | 14.40 |
| Consumer products | 165 | 11.00 |
| Electronic components | 203 | 13.53 |
| Services | 374 | 24.93 |
| Electronic equipment | 192 | 12.80 |
| Computer software | 128 | 8.53 |
| City | | |
| Beijing | 300 | 20.00 |
| Chengdu | 300 | 20.00 |
| Guangzhou | 300 | 20.00 |
| Shanghai | 300 | 20.00 |
| Tianjin | 300 | 20.00 |
| Total | 1,500 | 100.00 |

***Notes:*** [a] 'Others' include publicly traded or listed company, non-publicly-traded shareholding company or private, non-listed company, subsidiary or division of a domestic enterprise, joint venture of a domestic enterprise and others.

[b] 'Wholly domestic non-state owned' refers to those owned by domestic top manager or family, other domestic individuals, domestic institutional investors, domestic firms and domestic banks.

[c] Industries are ranked in ascending order of average firm skill intensity (ratio of skilled labour to unskilled labour).

or collectively owned firms, 12.1 percent are foreign joint ventures, 2.67 percent are subsidiaries of multinational firms and 47.9 percent belong to five other categories.[13] Based on ownership share, 17.5 percent are wholly state-owned, 41.7 percent are wholly domestic non-state owned,[14] 29.9 percent are majority foreign-owned, 6.6 percent are minority foreign-owned and 4.27 percent of the sample does not contain information on ownership share. Among the 1,500 firms, 381 (25.4 percent) exported in 1998. This number rose to 457 (30.5 percent) in 2000. The 1,500 firms belong to seven industries, with 222 in the apparel and leather good industry, 216 in the automobile industry, 165 in the industry of consumer products, 203 in the industry producing electronic components, 192 in the industry of electronic equipment, 128 in the computer software industry and 374 in various service industries.

Table 2 reports summary statistics of key variables. Firms in the sample vary considerably in size, factor intensity, R&D intensity and export intensity. Over the sample period of 1998–2000, firms on average grew in total sales, export sales, capital assets and R&D expenditure.[15] While the sample average of total employment fell from 686 in 1998 to 612 in 2000, the sample average of non-production labour employment rose from 138 in 1998 to 147 in 2000. In our study, we use employment of non-production workers as a proxy for employment of skilled workers, which equals the sum of engineering and technical personnel and managerial personnel. Table 2 reports that non-production employment varies significantly across firms, with a standard deviation of 636 in 1998 and 550 in 2000. We use production workers as a proxy for unskilled workers, which include basic production workers, auxiliary production workers and service personnel. The sample average of production employment is 463 in 1998 and 450 in 2000, and production employment also varies significantly across firms.

Table 2 also reports the sample mean of four intensity variables that characterize a firm. Skill intensity, defined as the ratio of skilled to unskilled employment, increased from 0.99 in 1998 to 1.40 in 2000.[16] The rise of firm skill intensity suggests that the relative demand for skilled workers increased over the sample period,

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[13] The five other categories are publicly traded or listed company, non-publicly traded shareholding company or private, non-listed company, subsidiary/division of a domestic enterprise, joint venture of a domestic enterprise and others.

[14] 'Wholly domestic non-state owned' refers to those owned by domestic top manager or family, other domestic individuals, domestic institutional investors, domestic firms and domestic banks.

[15] Output data are not available, so we use total sales as a proxy for $Y_n$. The current value of sales is converted to 1998 value using the GDP deflator calculated from the *China Statistical Yearbook*, 2001. The GDP deflator is 0.978 for 1999 and 0.986 for 2000, with 1998 as the base year. Notice that China experienced deflation in 1999 and 2000 with respect to 1998. We use the book value of a firm's fixed assets as a proxy for its capital stock $K_n$. The fixed assets cover buildings, production machinery and equipment, office equipment, vehicles and so on.

[16] Note that 0.99 and 1.40 are the mean values of $H_n/L_n$ in 1998 and 2000, respectively. Table 2 reports that the mean values of $H_n$ and $L_n$ are 138 and 463, respectively in 1998, and 147 and 450, respectively in 2000. These numbers are consistent with each other because of the uneven distribution of skilled and unskilled employment across firms in the sample.

**Table 2. Summary statistics of variables**

| Variable | Description | Mean (standard deviation) | | Change |
|---|---|---|---|---|
| | | 1998 | 2000 | 1998–2000 |
| $Y_n$ | Total sales, thousand Yuan, 1998 value[a] | 148.58 (1,002.10) | 210.25 (1,333.56) | 72.54 (898.96) |
| $X_n$ | Export sales, thousand Yuan, 1998 value | 18.31 (103.65) | 34.84 (178.04) | 16.53 (107.35) |
| $N_n$ | Number of workers | 686 (2,938) | 612 (2,537) | –26 (749) |
| $H_n$ | Number of non-production workers[b] | 138 (636) | 147 (550) | 8 (238) |
| $L_n$ | Number of production workers[c] | 463 (2,339) | 450 (2,151) | –18 (946) |
| $K_n$ | Capital assets, thousand Yuan, 1998 value[d] | 160.33 (1,538.62) | 198.73 (1,636.55) | 38.71 (393.79) |
| $R_n$ | R&D expenditure, thousand Yuan, 1998 value | 6.64 (115.64) | 9.021 (157.45) | 2.52 (53.78) |
| $H_n/L_n$ | Skill intensity | 0.99 (2.87) | 1.40 (5.81) | 0.04 (1.62) |
| $K_n/Y_n$ | Capital intensity | 3.79 (42.54) | 2.60 (28.34) | –1.05 (19.28) |
| $R_n/Y_n$ | R&D expenditure intensity | 0.07 (1.11) | 0.09 (1.22) | 0.002 (1.572) |
| $T_n/Y_n$ | R&D stock intensity[e] | NA | NA | 0.053 (0.758) |
| $X_n/Y_n$ | Export intensity | 0.16 (0.33) | 0.16 (0.33) | 0.006 (0.122) |
| $s_{nH}$ | Skilled wage share in total wage bill (%) | 40.30 (26.79) | 43.49 (27.27) | 1.72 (8.28) |

***Notes*:** [a] Conversion to 1998 value uses the GDP deflator calculated from the *China Statistical Yearbook*, 2001.

[b] Non-production workers include engineering and technical personnel, and managerial personnel.

[c] Production workers include basic production workers, auxiliary production workers, service personnel and other employees.

[d] Capital assets are measured by book value of the firm's fixed assets in buildings, production machinery and equipment, office equipment, vehicles and other fixed assets.

[e] R&D stock data are not available. Since the change in R&D stock between 1998 and 2000 is given by the sum of R&D expenditure in 1998 and 1999, the change in R&D stock intensity is approximated by the ratio of the sum of R&D expenditure in 1998 and 1999 to the sum of total sales in 1998 and 1999.

which we view as the driving force of rising wage inequality in China depicted in Figure 1. Capital intensity, defined here as the ratio of fixed capital assets to total sales, fell from 3.79 in 1998 to 2.60 in 2000.[17] R&D expenditure intensity, which indicates how much a firm invests in R&D as a share of income (approximated by sales), increased slightly in the sample period. In our regression, we use change in R&D stock intensity as the variable for technical change. While R&D stock data are not available, the change in R&D stock between 1998 and 2000 is given by the sum of R&D expenditure in 1998 and 1999, so the change in R&D stock intensity is approximated by the ratio of the sum of R&D expenditure in 1998 and 1999 to the sum of total sales in 1998 and 1999.[18] The sample means of export intensity are about the same in 1998 and 2000, but notice that the change in export intensity varies significantly across firms.

Our regression equation uses $\Delta s_{nH}$, change in the share of firm $n$'s wage payment to skilled workers in total wage payment, as the dependent variable. An increase in $s_{nH}$ implies an increase in the relative demand for skilled workers at the given relative skilled wage ($w_H/w_L$). To compute $s_{nH}$ for firm $n$, one needs data on the firm's employment of skilled and unskilled workers (which we have) and data on wages paid by the firm to both types of workers (which we do not have). While the World Bank survey reports labour compensation by work type, the information was only for one year (2000) and many firms failed to report it. Our approach is to rewrite $s_{nH}$ as:

$$s_{nH} \equiv \frac{w_H H_n}{w_L L_n + w_H H_n} = \frac{\omega H_n}{L_n + \omega H_n}$$

where $\omega \equiv (w_H/w_L)$. Without data on $\omega$ from the firm survey, we estimate its value based on data from the *China Labour Statistical Yearbook*.[19] Here the assumption is that the relative wage of skilled workers is the same for all firms. Using the relative-wage rates estimated from the statistical yearbook together with the firm employment data from the World Bank survey, we obtain $s_{nH}$ for each firm. The sample average of $s_{nH}$ is 40.3 percent in 1998 and it increases to 43.5 percent in 2000, suggesting an increase in relative demand for skilled labour over the period.

Table 3 reports firm characteristics by ownership, export status, industry and city. In the sample, domestic non-state firms had the highest skill intensity,

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[17] Capital intensity defined as capital–employment ratio shows the same trend. We choose $K_n/Y_n$ as the measure of capital intensity because the short-run cost function implies it as an independent variable in our regression equation (see the previous section).

[18] This method follows Machin and Van Reenen (1998).

[19] According to sample survey data of employees wage level in the *China Labour Statistical Yearbook* (2000), the average wage of workers with college education and above in 1998 is 12,819 Yuan and that of workers with junior middle school education and below is 8,593 Yuan. Using the former as a proxy for wage of skilled workers and the latter as a proxy for wage of unskilled workers, we have $\omega_{1998} = 1.492$. We use data from the *China Labour Statistical Yearbook* (2001) to obtain $\omega_{2000} = 1.642$.

**Table 3. Firm characteristics by ownership, export status, industry and city**

| | 1998 | 2000 | 1998–2000 | 1998 | 2000 | 1998–2000 |
|---|---|---|---|---|---|---|
| **Ownership** | | **Skill intensity** | | | **Capital intensity** | |
| State-owned | 0.712 | 0.738 | 0.018 | 8.644 | 7.438 | −0.959 |
| Domestic non-state | 1.176 | 1.752 | 0.023 | 1.862 | 1.547 | −0.328 |
| Majority foreign | 1.031 | 1.420 | 0.109 | 2.986 | 1.412 | −1.659 |
| Minority foreign | 0.622 | 0.760 | 0.025 | 2.638 | 1.737 | −0.967 |
| **Ownership** | | **R&D intensity** | | | **Export intensity** | |
| State-owned | 0.024 | 0.028 | 0.004 | 0.071 | 0.077 | 0.003 |
| Domestic non-state | 0.028 | 0.072 | 0.004 | 0.064 | 0.075 | 0.013 |
| Majority foreign | 0.124 | 0.145 | 0.013 | 0.363 | 0.337 | 0.013 |
| Minority foreign | 0.192 | 0.130 | −0.055 | 0.221 | 0.238 | 0.010 |
| **Export status** | | **Skill intensity** | | | **Capital intensity** | |
| Exporting | 0.596 | 0.613 | 0.044 | 2.578 | 1.251 | −1.485 |
| Non-exporting | 1.201 | 1.744 | 0.036 | 4.364 | 3.191 | −0.845 |
| **Export status** | | **R&D intensity** | | | **Export intensity** | |
| Exporting | 0.116 | 0.125 | 0.016 | 0.495 | 0.532 | 0.028 |
| Non-exporting | 0.044 | 0.072 | −0.005 | NA | NA | NA |
| **Industry** | | **Skill intensity** | | | **Capital intensity** | |
| Apparel and leather goods | 0.241 | 0.378 | 0.049 | 2.004 | 1.718 | −0.307 |
| Vehicles and vehicle parts | 0.340 | 0.340 | −0.001 | 4.538 | 2.981 | −1.336 |
| Consumer products | 0.378 | 0.415 | 0.024 | 1.887 | 1.804 | −0.302 |
| Electronic components | 0.447 | 0.418 | 0.004 | 1.832 | 1.870 | −0.347 |
| Services | 1.363 | 1.686 | 0.111 | 6.621 | 4.774 | −1.169 |
| Electronic equipment | 1.972 | 2.671 | 0.019 | 1.293 | 1.124 | −0.045 |
| Computer software | 4.631 | 6.566 | 0.027 | 7.763 | 1.491 | −6.430 |
| **Industry** | | **R&D intensity** | | | **Export intensity** | |
| Apparel and leather goods | 0.005 | 0.004 | −0.002 | 0.366 | 0.368 | 0.004 |
| Vehicles and vehicle parts | 0.286 | 0.076 | −0.210 | 0.107 | 0.110 | 0.009 |
| Consumer products | 0.037 | 0.017 | −0.019 | 0.121 | 0.140 | 0.013 |
| Electronic components | 0.028 | 0.046 | 0.011 | 0.340 | 0.347 | 0.004 |
| Services | 0.009 | 0.029 | 0.006 | 0.013 | 0.016 | 0.002 |
| Electronic equipment | 0.032 | 0.026 | 0.265 | 0.181 | 0.182 | 0.013 |
| Computer software | 0.112 | 0.325 | −0.009 | 0.044 | 0.033 | 0.003 |

**Table 3. (cont) Firm characteristics by ownership, export status, industry and city**

| | 1998 | 2000 | 1998–2000 | 1998 | 2000 | 1998–2000 |
|---|---|---|---|---|---|---|
| **City** | | **Skill intensity** | | | **Capital intensity** | |
| Beijing | 1.589 | 1.524 | 0.001 | 1.968 | 1.773 | −0.036 |
| Chengdu | 0.824 | 1.033 | 0.064 | 4.437 | 2.752 | −1.748 |
| Guangzhou | 0.814 | 1.850 | −0.072 | 2.010 | 1.258 | −0.922 |
| Shanghai | 1.062 | 1.070 | 0.152 | 7.699 | 4.456 | −2.507 |
| Tianjin | 0.600 | 0.744 | 0.056 | 2.923 | 2.735 | −0.079 |
| **City** | | **R&D intensity** | | | **Export intensity** | |
| Beijing | 0.075 | 0.077 | −0.015 | 0.094 | 0.094 | 0.007 |
| Chengdu | 0.034 | 0.102 | 0.003 | 0.037 | 0.049 | 0.012 |
| Guangzhou | 0.035 | 0.056 | −0.006 | 0.351 | 0.323 | −0.001 |
| Shanghai | 0.180 | 0.025 | −0.160 | 0.179 | 0.173 | 0.004 |
| Tianjin | 0.019 | 0.181 | 0.183 | 0.166 | 0.177 | 0.010 |

followed closely by majority foreign-owned firms. The skill intensities of state-owned firms and minority foreign-owned firms were low. Notice that all ownership groups experienced a rise in skill intensity, with majority foreign-owned firms having much faster growth in skill intensity than other firms. All ownership groups experienced a decrease in capital intensity during the sample period. Notice that capital intensity was much higher in state-owned firms than other firms, while R&D intensity and export intensity were much higher in foreign firms than domestic firms.

Interestingly, non-exporting firms had both skill intensity and capital intensity that were more than twice as high as exporting firms. R&D intensity of exporting firms, however, was about twice as high as that of non-exporting firms, although the gap had narrowed between 1998 and 2000. The ranking of industries in skill intensity and capital intensity is consistent with the conventional view. For example, the apparel industry was the most unskilled-labour intensive, the automobile industry was the most capital-intensive, and the computer software industry was the most skilled-labour intensive and most R&D-intensive. Not surprisingly the data show that export intensity was the highest in the apparel industry and electronic component industry. Almost all industries (except for the automobile industry) experienced rising skill intensity between 1998 and 2000, and all industries experienced falling capital intensity and rising export intensity in the period.

Statistics on the cities are also interesting. Beijing had the highest average firm skill intensity in 1998 but was surpassed in 2000 by Guangzhou. The growth rate of skill intensity is much higher in Shanghai than the other four cities. Shanghai remained the most capital-intensive city despite a sharp decrease in its capital intensity over the period, and Guangzhou remained the most export-intensive city

**Table 4. Regression results: Role of ownership, technology and trade**

| Sample | (1) All | (2) Non-state | (3) Non-state |
|---|---|---|---|
| $\Delta \ln(K_n/Y_n)$ | 0.404 (0.136)*** | 0.408 (0.148)*** | |
| $\Delta \ln(Y_n)$ | 0.581 (0.151)*** | 0.587 (0.158)*** | |
| $\Delta(T_n/Y_n)$ | 0.067 (0.133) | 0.059 (0.136) | |
| $\Delta(X_n/Y_n)$ | −0.919 (0.469)** | −0.886 (0.486)* | |
| $D_E \Delta \ln(K_n/Y_n)$ | | | 0.348 (0.213)* |
| $D_E \Delta \ln(Y_n)$ | | | 0.653 (0.281)** |
| $D_E \Delta(T_n/Y_n)$ | | | 0.137 (0.059)** |
| $D_E \Delta(X_n/Y_n)$ | | | −1.334 (0.658)** |
| $D_{NE} \Delta \ln(K_n/Y_n)$ | | | 0.468 (0.174)*** |
| $D_{NE} \Delta \ln(Y_n)$ | | | 0.538 (0.183)*** |
| $D_{NE} \Delta(T_n/Y_n)$ | | | −0.232 (0.046)*** |
| Dummy for state-owned | −0.851 (0.351)** | | |
| Dummy for foreign-owned | 0.016 (0.143) | −0.025 (0.130) | −0.021 (0.125) |
| Industry fixed effects | Yes | Yes | Yes |
| City fixed effects | Yes | Yes | Yes |
| $R^2$ | 0.040 | 0.042 | 0.053 |
| Observations | 1,151 | 924 | 924 |

***Notes*:** The dependent variable is $\Delta s_{nH}$, change in share of skilled wage in a firm's wage bill. Δ denotes time difference between 1998 and 2000.
See Table 2 for definitions of the independent variables.
$D_E$ and $D_{NE}$ are dummy variables for exporting firms and non-exporting firms, respectively.
Numbers in parentheses are heteroskedasticity-adjusted standard errors.
*** indicates statistical significance at the 1% level, ** 5% level and * 10% level.

despite a decrease in its export intensity over the period. Notice that R&D intensity in Shanghai was more than twice that of Beijing, five times that of Chengdu and Guangzhou, and nine times that of Tianjin. While 300 firms in a city are not likely to be a close representation of the population of thousands of firms in the city, the statistics shown in Table 3 are consistent with people's general perception of these cities.

## 4. Results

Tables 4–6 report regression results. The dependent variable is change in share of wage payment to skilled workers in a firm's total wage payment. As discussed in the previous section, this variable measures the change in a firm's relative demand

**Table 5. Regression results: Role of foreign firms**

| | (4) Non-state | | (5) Non-state |
|---|---|---|---|
| $D_F\, \Delta \ln(K_n/Y_n)$ | 0.265 (0.116)** | $D_{MAJ}\, \Delta \ln(K_n/Y_n)$ | 0.287 (0.112)*** |
| $D_F\, \Delta \ln(Y_n)$ | 0.457 (0.133)*** | $D_{MAJ}\, \Delta \ln(Y_n)$ | 0.403 (0.127)*** |
| $D_F\, \Delta(T_n/Y_n)$ | 0.058 (0.137) | $D_{MAJ}\, \Delta(T_n/Y_n)$ | 0.226 (0.030)*** |
| $D_F\, \Delta(X_n/Y_n)$ | −0.873 (0.540) | $D_{MAJ}\, \Delta(X_n/Y_n)$ | −0.540 (0.617) |
| | | $D_{MIN}\, \Delta \ln(K_n/Y_n)$ | 0.715 (0.344)** |
| | | $D_{MIN}\, \Delta \ln(Y_n)$ | 0.963 (0.346)*** |
| | | $D_{MIN}\, \Delta(T_n/Y_n)$ | −0.263 (0.037)*** |
| | | $D_{MIN}\, \Delta(X_n/Y_n)$ | −1.000 (0.835) |
| $D_{NF}\, \Delta \ln(K_n/Y_n)$ | 0.489 (0.225)** | $D_{NF}\, \Delta \ln(K_n/Y_n)$ | 0.486 (0.225)** |
| $D_{NF}\, \Delta \ln(Y_n)$ | 0.662 (0.249)*** | $D_{NF}\, \Delta \ln(Y_n)$ | 0.660 (0.249)*** |
| $D_{NF}\, \Delta(T_n/Y_n)$ | 0.332 (0.775) | $D_{NF}\, \Delta(T_n/Y_n)$ | 0.325 (0.777) |
| $D_{NF}\, \Delta(X_n/Y_n)$ | −0.927 (1.010) | $D_{NF}\, \Delta(X_n/Y_n)$ | −0.935 (1.012) |
| Industry fixed effects | Yes | Industry fixed effects | Yes |
| City fixed effects | Yes | City fixed effects | Yes |
| $R^2$ | 0.043 | $R^2$ | 0.052 |
| Observations | 924 | Observations | 924 |

***Notes*:** The dependent variable is $\Delta s_{nH}$, change in share of skilled wage in a firm's wage bill. Δ denotes time difference between 1998 and 2000.
See Table 2 for definitions of the independent variables.
$D_F$ and $D_{NF}$ are dummy variables for foreign firms and non-state domestic firms, respectively. $D_{MAJ}$ and $D_{MIN}$ are dummy variables for foreign majority-owned firms and foreign minority-owned firms, respectively.

for skilled workers. The estimation method is ordinary least squares, with estimated standard errors heteroskedasticity-adjusted. To capture the larger effect on relative skill demand from larger firms, we follow the literature by using a firm's wage bill share as the weight. Our estimation pools data across firms and controls for unobserved industry-specific effects and city-specific effects.

Regression (1) in Table 4 reports results from the full sample. The estimated coefficient on capital deepening, $\Delta(K_n/Y_n)$, is positive and statistically significant. This implies that capital complements skill, in other words, higher capital intensity is associated with higher relative demand for skilled labour. The estimated coefficient on change in total sales ($\Delta Y_n$), a proxy for change in output, is also positive and statistically significant. This implies that larger firms have higher relative demand for skilled workers, which is consistent with the finding in other studies (such as Feenstra and Hanson, 1999, Table 3).

**Table 6. Regressions by industry (sample of non-state firms)**

| | (6) Apparel and leather good | (7) Vehicles and vehicle parts | (8) Consumer products | (9) Electronic equipment | (10) Services | (11) Electronic components | (12) Computer software |
|---|---|---|---|---|---|---|---|
| Skill intensity | 0.310 | 0.340 | 0.397 | 0.433 | 1.525 | 2.322 | 5.599 |
| $\Delta \ln(K_n/Y_n)$ | 0.360 (0.127)*** | 1.146 (0.883) | 0.215 (0.226) | 0.394 (0.272) | 0.026 (0.041) | 0.253 (0.214) | 0.314 (0.119)*** |
| $\Delta \ln(Y_n)$ | 0.509 (0.139)*** | 1.524 (1.001) | 0.345 (0.171)** | 1.010 (0.379)*** | 0.101 (0.047)** | 0.313 (0.270) | 0.465 (0.126)*** |
| $\Delta(T_n/Y_n)$ | 2.316 (1.296)* | −0.086 (0.156) | −0.879 (0.406)** | −0.290 (0.386) | 0.615 (0.603) | 10.484 (6.152)* | −0.023 (0.194) |
| $\Delta(X_n/Y_n)$ | −0.409 (0.148)*** | −4.186 (1.925)** | 0.344 (0.465) | −1.500 (1.292) | 0.713 (1.516) | 0.423 (1.302) | −0.544 (0.865) |
| City fixed effects | Yes | Yes | Yes | Yes | Yes | Yes | Yes |
| $R^2$ | 0.202 | 0.060 | 0.068 | 0.254 | 0.053 | 0.142 | 0.545 |
| Observations | 147 | 155 | 112 | 141 | 192 | 117 | 60 |

***Notes*:** The dependent variable is $\Delta s_{nH}$, change in share of skilled wage in a firm's wage bill.
Industries are ranked in ascending order (from left to right) of skill intensity averaged over 1998–2000.

Regression (1) shows that change in R&D stock intensity, $\Delta(T_n/Y_n)$, a measure of technical progress, has an effect on relative skill demand that is not statistically different from zero. This finding suggests that technical progress is on average skill-neutral in the full sample. In contrast, change in export intensity, $\Delta(X_n/Y_n)$, has a negative and statistically significant effect on relative skill demand. This finding suggests that goods exported by these firms are on average relatively intensive in unskilled labour.

What is the role of ownership in determining relative skill demand? This is a question of great interest in the context of the Chinese economy. Regression (1) shows that the estimated coefficient on the state ownership dummy is negative and statistically significant.[20] Moreover, the quantitative effect is estimated to be large. For the 1,151 firms in this regression, state-owned firms account for 19.7 percent. If 10 percent of these firms were privatized, it would imply a skilled wage share increase of 0.0168, which would account for 21 percent of rising skill demand in the sample period.[21] By contrast, the estimated coefficient on the dummy for foreign firms is not statistically different from zero. This suggests that foreign firms and domestic non-state firms do not differ in the rate of skill upgrading.

Regression (1) uses the full sample that contains both state-owned and non-state-owned firms. Since the employment decision of state-owned firms in China is to a large extent not market-based, our regression equation derived from cost minimization may not be applicable to them. Because of this consideration, our remaining regressions will apply only to non-state firms. Nevertheless, we find that the results from regression (2) that uses the sample of non-state firms are similar to those from regression (1) that uses the full sample. Following the method of Feenstra and Hanson (1999), we estimate that capital deepening and firm size expansion account for about 2 percent and 6 percent, respectively, of rising skill demand in the sample period.[22]

The finding of skill-neutral technical progress in regressions (1) and (2) is distinctive for China.[23] This finding seems specific, however, to the sample period of 1998–2000 and should not be interpreted as general evidence of no skill-biased

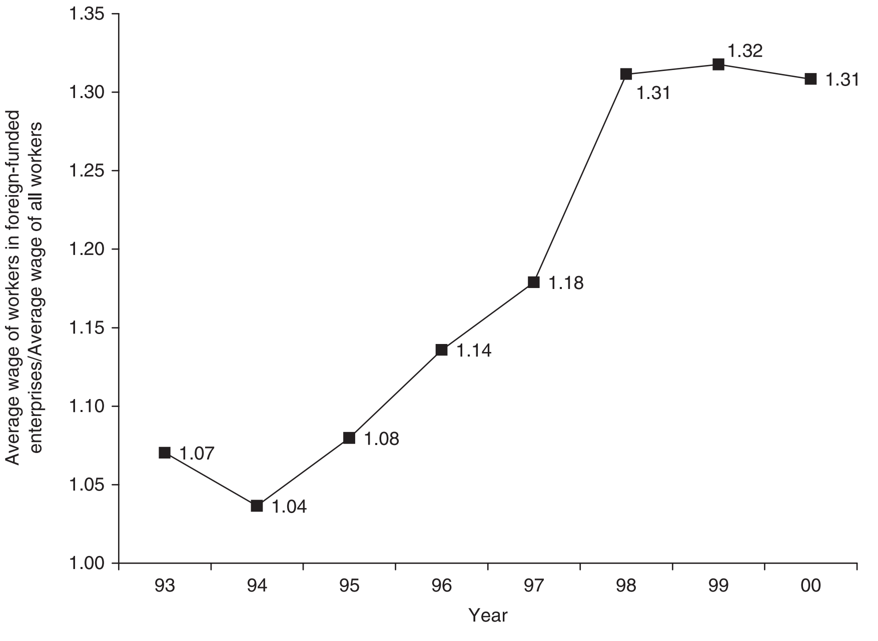
[20] The survey provides information on a firm's legal status and ownership share. Because ownership share defines firm ownership more accurately and the data are more complete, we use it to classify firms. In our study, state-owned firms refer to firms owned entirely by government, foreign firms refer to firms with some foreign ownership, and the remaining are non-state owned domestic firms (Table 1).

[21] The mean of the state ownership dummy variable is 0.197, the estimated coefficient on the state ownership dummy variable is –0.851, so the effect of privatization of 10 percent of state-owned firms equals $0.197 \times 0.1 \times 0.851 = 0.0168$. The mean value of change in skilled wage share in total wage bill (weighted) is 0.08, so the contribution of the privatization equals $0.0168/0.08 = 21\%$.

[22] The mean value of $\Delta \log(K_n/Y_n)$ for non-state firms is 0.004, so its estimated effect equals $0.004 \times 0.408 = 0.0016$. The mean value of change in skilled wage share in total wage bill (weighted) is 0.08, so the contribution of capital deepening equals $0.0016/0.08 = 2\%$. Similarly, we obtain the contribution of firm size expansion equal to $0.0078 \times 0.587/0.08 = 6\%$.

[23] Studies of other countries usually find skill-biased technical progress responsible for rising wage inequality. See Berman, Bound and Machin (1998), and the papers cited in the introduction.

**Figure 2. Wage premium for workers in foreign-funded enterprises in China, 1993–2000**




technical change in China. Figure 2 shows the average wage of workers in China's foreign-funded enterprises relative to the average wage of all workers (that is, the wage premium for workers in foreign-funded enterprises). Notice that the wage premium changed little during 1998–2000, which suggests that skill demand was insensitive to expansion of foreign direct investment in this period.

However, while technical progress was on average skill-neutral, we find that it was skill-biased in exporting firms and unskilled-biased in non-exporting firms. In regression (3), we introduce dummy variables for exporting firms ($D_E$) and non-exporting firms ($D_{NE}$), respectively, and interact them with the explanatory variables. The estimated effects of capital deepening and size expansion are found to be similar between exporting and non-exporting firms, but the estimated effects of technical progress are sharply different. For exporting firms, we find a positive and statistically significant estimated coefficient on $\Delta(T_n/Y_n)$, and for non-exporting firms the estimated coefficient on $\Delta(T_n/Y_n)$ is negative and statistically significant. Regression (3) shows that export expansion has two opposite effects on change in relative skill demand. On the one hand, export expansion has a direct effect, captured by the estimated coefficient on $\Delta(X_n/Y_n)$, which decreases the relative demand for skilled workers. This direct effect is consistent with the Heckscher–Ohlin prediction for a labour-abundant country. On the other hand, we find a positive indirect effect of exporting through inducing skill-biased technical progress. This indirect effect is consistent with the prediction of some recent models (Acemoglu, 1998; Wood, 1994) in which trade openness enhances diffusion of skill-biased technologies from developed countries to developing countries. A calculation with our sample indicates that the net effect is positive, suggesting that China's rising export openness has contributed to rising skill demand and consequently rising wage inequality in China. Quantitatively this net effect accounts for 5 percent of rising skill demand in the sample period.[24]

Next, we examine the influence of foreign direct investment on China's rising skill demand. Table 5 reports the results. In regression (4), we introduce dummy variables for foreign firms ($D_F$) and domestic non-state firms ($D_{NF}$), respectively, and interact them with the explanatory variables. We find that the estimated effects of all explanatory variables are quite similar between foreign firms and domestic non-state firms. In particular, the estimated coefficients on $\Delta(T_n/Y_n)$ are not statistically different from zero in both foreign firms and domestic non-state firms, suggesting that technical progress is on average skill-neutral in both firm groups.

While technical progress is on average skill-neutral for foreign firms, we find that it is skill-biased in majority foreign-owned firms and unskilled-biased in minority foreign-owned firms. It is well known that majority ownership significantly increases a foreign firm's power in decision making. In regression (5), we introduce dummy variables for majority foreign-owned firms ($D_{MAJ}$) and minority foreign-owned firms ($D_{MIN}$), respectively, and interact them with the explanatory variables. We find a sharp contrast in the estimated coefficient on $\Delta(T_n/Y_n)$ between the two types of foreign firms. For majority foreign-owned firms this estimated coefficient is positive and statistically significant at the 1 percent level; we interpret this as strong evidence of skill-biased technical progress in these firms. For minority foreign-owned firms this estimated coefficient is negative and statistically significant at the 1 percent level; we view this as evidence that technical progress in minority foreign-owned firms was biased towards unskilled labour.

Why is there such a sharp difference? To provide an explanation, we observe that minority foreign-owned firms had much lower skill intensity than majority foreign-owned firms (Table 3). In fact, minority foreign-owned firms had the lowest skill intensity among all ownership groups. According to the recent literature on endogenous technology bias (for example, Acemoglu, 1998), the factor bias of technical progress depends endogenously on factor intensity. A firm with higher skill intensity has an incentive to adopt technology that complements skilled labour, while a firm with lower skill intensity has an incentive to adopt technology that complements

[24] The mean value of $\Delta(T_n/Y_n)$ for exporting firms is 0.09, so the indirect effect equals $0.09 \times 0.137 = 0.012$. The mean value of $\Delta(X_n/Y_n)$ is 0.006, so the direct effect equals $0.006 \times (-1.334) = -0.008$. Therefore the net effect equals 0.004. The mean value of change in skilled wage share in total wage bill (weighted) is 0.08, so the contribution of export expansion equals $0.004/0.08 = 5\%$.

unskilled labour. Applying this theory, majority foreign-owned firms in China may have spent R&D funds mainly to improve technologies that complement skilled workers, which would raise the relative skill demand, while minority foreign-owned firms may have spent R&D funds mainly to improve technologies that complement unskilled workers, which would lower the relative skill demand. Quantitatively, we find that skill-biased technical progress in majority foreign-owned firms accounts for about 22 percent of rising skill demand in the sample period.[25]

To gain further insight into the role of trade openness and technical progress in determining China's rising skill demand, we run regressions for the seven industries, respectively. In Table 6, we report the results. Industries are ranked in ascending order of skill intensity (averaged over 1998 and 2000) from left to right. The two most unskilled-intensive industries are the apparel and leather goods industry, and the vehicles and vehicle parts industry. In these two industries, we find that change in export intensity has a negative and statistically significant estimated effect on change in relative skill demand. That is, higher export intensity is associated with lower relative skill demand in unskilled-intensive industries, consistent with the prediction of the Heckscher–Ohlin trade model. For the five more skill-intensive industries, we find no effect of export expansion on change in relative skill demand. The industry-level regressions in Table 6 also show the technology effect. As expected from the theory of endogenous technology bias, we find that the electronic components industry, which is relatively skill-intensive, experienced skill-biased technical change and the consumer product industry, which is relatively unskilled-intensive, experienced technical progress biased towards unskilled labour. We find, however, that the apparel and leather goods industry, which is most unskilled-intensive, experienced skill-biased technical progress. One explanation is that the relative price of apparel and leather goods may have declined in the world market that sufficiently reduced the incentive to develop technologies complementary to unskilled workers. In models of endogenous technology bias (such as Acemoglu, 1998), technology bias depends on two factors: factor intensity and relative commodity price. While lower skill intensity of the apparel and leather industry would have induced firms to spend R&D on improving unskilled labour-using technologies (a market size effect), the decline in relative price of apparel and leather goods would have induced technology innovations biased against unskilled labour (a price effect). If the price effect dominates the market size effect, technical change in unskilled-labour intensive industries will be skill-biased rather than unskilled-biased. This may be the case for the apparel and leather industry in China.

[25] The mean value of $\Delta(T_n/Y_n)$ for majority foreign-owned firms is 0.078, so its estimated effect equals $0.078 \times 0.226 = 0.0176$. The mean value of change in skilled wage share in total wage bill (weighted) is 0.08, so the contribution of skill-biased technical progress in majority foreign-owned firms equals $0.0176/0.08 = 22\%$.

**Table 7. Regressions by city (sample of non-state firms)**

| | (13) Beijing | (14) Chengdu | (15) Guangzhou | (16) Shanghai | (17) Tianjin |
|---|---|---|---|---|---|
| $\Delta \ln(K_n/Y_n)$ | 0.716 (0.459) | 0.818 (0.390)** | 0.072 (0.118) | 0.108 (0.125) | 0.174 (0.104)* |
| $\Delta \ln(Y_n)$ | 1.029 (0.494)** | 0.850 (0.393)** | 0.351 (0.134)*** | 0.211 (0.163) | 0.225 (0.137)* |
| $\Delta(T_n/Y_n)$ | –0.315 (0.117)*** | 1.619 (1.827) | –0.620 (0.445) | 0.249 (0.051)*** | –0.185 (0.227) |
| $\Delta(X_n/Y_n)$ | –1.631 (1.030) | 0.013 (0.526) | –0.766 (0.892) | –1.096 (0.964) | 0.061 (1.053)*** |
| Industry fixed effects | Yes | Yes | Yes | Yes | Yes |
| $R^2$ | 0.055 | 0.216 | 0.164 | 0.175 | 0.039 |
| Observations | 212 | 191 | 177 | 177 | 167 |

***Note***: The dependent variable is $\Delta s_{nH}$, change in share of skilled wage in a firm's wage bill.

It is also interesting to run the regressions for the five cities, respectively. Table 7 reports the results. The most noticeable difference between cities is that technical progress was unskilled labour-biased in Beijing, the capital of China, but was skill-biased in Shanghai, the city most attractive to multinational enterprises in recent years. The estimated technology effects in the other three cities are skill-neutral. In terms of the trade effect, we find no statistically significant effect of change in export intensity on change in relative skill demand in all cities except for Tianjin.

## 5. Conclusion

China has experienced a sharp increase in wage inequality between unskilled and skilled workers since the late 1990s, which has contributed to the country's fast growing income inequality. With relative supply of skilled workers also increasing, the rise in wage inequality must have been caused by the rise in relative demand for skilled labour. In this paper, we investigate the impact of trade opening and technical progress on China's rising skill demand, using data from a World Bank survey of 1,500 firms in five major cities of China for the period 1998–2000.

Our empirical analysis yields three main findings. First, we find that export expansion had a negative direct effect on relative skill demand, consistent with the Heckscher–Ohlin model prediction for a labour-abundant developing country. This direct negative effect of exporting was accompanied, however, by a positive indirect effect that works through the technology adoption of the firm. We find that export status was a key determinant of whether a firm's technical progress was skill-biased. During the sample period exporting firms experienced skill-biased technical progress while non-exporting firms did not, which we interpret as evidence of export-induced skill-biased technical change. In assessing the role played by international trade in China's rising skill demand and wage inequality, both the direct effect and the indirect effect should be considered. Based on our sample, we find that the indirect effect of export expansion dominates the direct effect, and the net effect is estimated to account for 5 percent of rising skill demand of the sample firms.

Second, we find that technical change in Chinese firms was on average skill-neutral, but the factor bias of technical change differs greatly across different types of firms. In particular, we find a sharp difference in the bias of technical change between firms with majority foreign ownership and those with minority foreign ownership. During the sample period, the former experienced skill-biased technical progress, while the latter experienced technical progress biased towards unskilled labour. Skill-biased technical progress in majority foreign-owned firms is estimated to account for 22 percent of rising skill demand of the sample firms.

Third, we find that the rate of skill upgrading was significantly lower in China's state-owned firms than in non-state owned firms. This implies that as China privatizes more state-owned firms and as non-state firms continue to grow faster than state-owned firms, China will have a further increase in relative skill demand and wage inequality. Based on our sample, a further privatization of 10 percent of the state-owned firms in 1998–2000 would contribute 21 percent to rising skill demand in the period. In contrast, we find no significant difference in rate of skill upgrading between foreign firms and non-state-owned domestic firms.

Identifying the reasons behind China's rising skill demand and wage inequality is of both academic interest and policy value. The pervasive non-market elements in the Chinese economy make such a study a challenging task, and lack of data imposes additional difficulty on such a study. This paper provides a first step towards a better understanding of China's rising skill demand and wage inequality in association with foreign trade, foreign direct investment, technical progress, and privatization. It is worth noting that due to data limitation we are not able to perform robustness checks of our results with different estimation approaches as in Feenstra and Hanson (1999), and we ask the reader to interpret our results with caution. Further research is needed to overcome the limitations of this paper and explore the topic in more depth.

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