UNIVERSITY OF ALBERTA
FACULTY OF ARTS
Department of Economics

Working Paper No. 2013-12

Privatization in China: Technology and Gender in the Manufacturing Sector

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September, 2013

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Abstract

This paper examines the impact of privatization on gender discrimination in China across firms with different technology intensities. Using a comprehensive firm-level survey, the paper identifies gender wage-productivity differentials by directly estimating the relative productivity levels of workers from the production function of firms. The panel structure of the survey is taken advantage of by following firms that were fully state-owned in the initial year, and distinguishing them from firms that were later privatized. The main results show that privatization was associated with an increase in relative productivity of female workers in high technology industries, and a reduction in relative productivity of female workers in low technology industries. Time varying coefficient results suggest that the improvements in gender outcomes in high technology industries may not be maintained in the long run as the relative wage and productivity ratios tend to deteriorate, potentially due to low supply of highly educated female workers. At the same time, outcomes in privatized low technology industries tend to improve over time, lowering the wage and productivity gaps between male and female workers.

Keywords: Discrimination, Gender, Privatization, Technology
JEL Classification: J16, J31, P20.

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1 Introduction

During the last two decades, China has experienced a gradual economic transformation from a centrally-planned to a market-oriented economy, as the Chinese government established a series of reforms aimed at the restructuring of state-owned firms. As a result, the private sector accounted for more than 40 percent of national industrial output and employment in 2001, while state-owned firms accounted for only 23 percent. This is in stark contrast to the structure which existed in 1980, when the state sector contributed to 76 percent of the national industrial output (Liu et al., 2006).

While the effect of privatization on gender outcomes is a widely discussed topic in the literature, the few studies in the literature do not provide a clear picture. Dong and Bowles (2002) reported that wage gaps existed under all firm ownership types, including state-owned and privately-owned, while Dong et al. (2004) reported that privatization contributed to an increase in the disparity between males and females in the township and village enterprises of the rural Jiangsu and Shandong provinces. In particular, the authors found that privatization had accentuated the gender wage gap, income gap, and discrimination. Similarly, Liu et al. (2000) found that firm privatization led to a larger wage differential between the genders as workers' human capital characteristics were more appropriately rewarded.

There is also little known about how technology has impacted the extent to which increased competition affected gender outcomes. If technology reduces the demand for factors that are more abundant in male workers, technological improvements should increase women's relative wage and employment (Weinberg, 2000; Juhn et al., 2012; Ng, 2006). Because high technology industries are more likely to adopt computerized technologies, increased competition could differentially benefit women in these sectors. On the other hand, in low technology industries where female workers have comparative disadvantage, increased competitive pressures would lead to a reduction in relative productivity and earnings of female workers as employers reorganize labor to improve efficiency. While there is a growing literature on the relationship between technology and demand for female workers, to the best of our knowledge there is no work investigating how increased competi-

tion differentially affects discriminatory outcomes across industries with different technology intensities.

This paper investigates the impact of privatization on gender wage and productivity differentials in China. By following low-technology and high-technology firms through the privatization process, this paper identifies how privatization differentially affected women in firms with different technological intensities. It aims to understand how privatization balances out the labor markets by reallocating and appropriately awarding workers with respect to their human capital endowments and comparative advantages. Particularly, the paper considers the complementarity between female labor and technology to investigate the privatization-induced changes in relative wages and relative productivity levels of female workers. This aspect of privatization and how it interacts with labor market outcomes has been largely overlooked in the literature.

A nontrivial strength of the evidence provided in this paper is that it uses a comprehensive population-wide survey of Chinese manufacturing firms. This panel survey covers all state-owned firms, as well as all medium and large size non-state firms in China (Bai et al., 2009). In the literature, the investigations of gender-specific impacts are generally based on smaller cross-sectional surveys of specific geographical regions (eg. Dong and Zhang, 2009; Dong et al.. 2004; Liu et al., 2000). The national coverage of the survey in this paper allows us to accurately identify what is happening to gender outcomes through privatization across firms with different technology intensities. In addition, the paper relies on time-varying coefficients, which allows us to determine whether the impacts of privatization were driven by wages, worker productivity, or both simultaneously.

In order to investigate gender discrimination, we use a methodology that compares women's relative wages to their relative productivity levels by directly estimating worker productivity from the production function of firms. This methodology, introduced by Hellerstein and Neumark (1999), has the advantage of avoiding the potential bias in individual-level wage equations due to the reliance on observable individual-level characteristics to estimate the productivity differences between workers. Because these characteristics do not account for all factors that affect worker productivity, the unexplained portion is likely to be overestimated, leading to an interpretation of some of the productivity differences as employers'

discrimination.[1] In this paper, the productivity equation and the wage equation are simultaneously estimated using nonlinear least squares, while accounting for a wide range of firm characteristics. Following Dong and Zhang (2009), the within-industry discrimination is then identified by testing whether the wage differentials between the genders are explained by the productivity differentials.

The main results suggest that the impact of firm privatization on the relative productivity of female workers is consistent with their comparative advantages. That is, privatization is associated with higher relative female productivity in high technology industries, and lower relative female productivity in low technology industries when compared to the firms that remained as state-owned. In addition, privatized firms in high technology industries moved towards a competitive equilibrium where the gender wage ratio is consistent with the gender productivity ratio and workers are paid their relative marginal product. On the other hand, reduction in relative productivity in low technology sectors was not accompanied by a reduction in relative wages, thus moving away from the competitive equilibrium. However, according to the results with time-varying coefficients, the improvements in high technology sector are not sustainable in the long run, potentially due to low supply of highly educated female workers. Both relative wages and relative productivity levels are decreasing over time in privatized high technology firms when compared to the firms that remained as state-owned. In low technology sectors, the outcomes tend to improve over time as gender productivity ratio low technology sectors tend to increase along with their relative wages.

While there is a wide literature about gender earnings gap and discrimination in the manufacturing sector, there is still little known about the mechanisms through which competition reinforces efficiency in a labor market where male and female workers have different comparative advantages. This paper contributes and extends the literature by documenting evidence from China by following state-owned firms through the privatization process, and shows that privatization has led to a more competitive outcome in high technology industries by eliminating the wage premia paid to female workers. The paper shows that competition helps

[1]The literature based on individual level surveys have identified significant gender wage discrimination in China among migrant workers (Magnani and Zhu, 2013), and across different components of compensation (Xiu and Gunderson, 2013).

narrow down the productivity gap between male and female workers particularly in industries where female workers have a comparative advantage, while widening the productivity gap where they have comparative disadvantage. The results presented in this paper highlight that the impact of privatization on gender differentials works not only through changes in relative wages, but more importantly, through changes in relative productivity of male and female workers.

2 Background

The effect of privatization on gender earnings inequality is a widely discussed topic in the literature, with two main competing theories. The first theory states that the emphasis on equality in public ownership may be associated with less gender discrimination, in which case, the development of the private sector is expected to increase gender wage differentials (Meng and Miller, 1995). The second theory states that, under perfect competition, employers cannot sustain the higher production costs associated with inefficient practices, such as discrimination. Preference-based discrimination, as suggested by neoclassical theory, should not prevail in competitive markets (Becker, 1957; Liu et al., 2000). Therefore, whether or not privatization leads to greater gender wage discrimination is largely an empirical question.

According to Becker's model, discrimination is a costly practice. If employers have a taste for discrimination, they would be willing to pay in order to indulge this taste. It is also an inefficient practice, as these discriminating employers would hire less than the optimal number of women and would thus be sacrificing profit. Introducing a competitive environment into an industry that was previously state-owned is likely to wipe out the firms that discriminate, as the firms that do not practice discrimination would be more efficient. As a result, an increase in competition would reduce the wage differentials between men and women with comparable characteristics. Industry-level studies, such as Black and Brainerd (2004) and Menon and Rodgers (2009), have shown that a higher level of competition is associated with improvements in the gender gaps within the manufacturing sector. Specifically, they find that more competition leads to a higher reduction in residual gender gaps for industries that are initially more concentrated.

The industry-level association between competition and residual gender gaps overlooks the fact that competition can also differentially affect the productivity of male and female workers. Increased competition induces firms to adopt better technologies in order to improve efficiency. It is well-known that technological changes tend to favor female workers, regardless of whether or not they posses a higher ability relative to men (Galor and Weil, 1996; Weinberg, 2000; Black and Spitz-Oener, 2010). As a result, the gender wage differential in knowledge-based sectors, where female workers are likely to have a comparative advantage, tends to be narrower and decline relatively faster than in other sectors (Ural et al., 2009).[2] This paper differentiates firms with different technology intensities, in order to compare gender wage and gender productivity gaps over time, and investigates how they differed through the privatization process by focusing specifically on state-owned and privatized firms in China.

If female workers have differential productivity gains across industries, then privatization will alter possible discriminatory outcomes, not only through the gender-specific changes in wages, but also through the gender-specific changes in worker productivity. An increase in the relative value-added of female workers in high technology industries may be accompanied by an increase in their relative wages. This could be mistakenly interpreted as reduced discrimination if one focuses on employment surveys that use individual-level data, as these studies rely on human capital to measure their productivity. Worker productivity also depends on the productivity of the firm, how skills complement the technology used by the firm, and how these differences depend on the gender-specific endowments. In this paper, we estimate worker productivity directly from the firm survey in order to capture these firm-level factors. This approach circumvents the need for relying on observed worker characteristics in the wage equation to account for worker productivity.

In China, there is virtually no gender gap in primary education, with enrollment rates of 99 percent for both genders. However, according to World Bank (2006), substantial differences emerge when moving up the education scale. For example, the proportion of female students enrolled in high school was only 44 percent in

[2]This gender-specific comparative advantage was defined theoretically in Galor and Weil (1996).

2002, and the sex ratio was 1.46 among undergraduate students and 1.64 among graduate students (i.e. there were 1.64 male students for each female student). The evidence in the literature suggests that the return to education in China is higher for females relative to males (Zhang, 2005). This is due to the relatively low supply of highly educated women, as fewer women have received college degrees compared to men (Li, 2003; Gao et al., 2013). Deolaikar (1993) argued that the higher return to education among women is related to the technology employed in the manufacturing sector. Because male workers have a comparative advantage in physical strength which is utilized in unskilled positions, schooling is more important and more rewarding to women who focus on more skill intensive jobs. Consistent with this argument, Ren and Miller (2012) found that overeducated females are at an advantage compared to their male counterparts, while the wage penalty for the undereducated is greater for female workers. In this case, female workers within the high technology sector, where there is more of a demand for education, is likely to have an advantage in terms of the returns to labor when compared to female workers in low technology industries.

Prior to its market liberalization, the Chinese labor market was characterized by low levels of gender differentials. The state had the full responsibility of employment assignments; firms did not have the right to recruit an employee, and workers did not have the right to choose a job. Although wages were determined according to individuals' level of education and experience, their skill and performance levels were ignored. This system created a labor market where there is little gender wage gap (Liu, 2011). In addition, Knight and Song (1991) argue that the skill-mismatch between workers and tasks was prevalent in state-owned firms due to government's commitment to inequality. Market reforms, and the subsequent labor retractions that followed, have led firms to reorganize their workforces in order to achieve greater efficiency. Some have argued that labor retractions following these reforms have particularly affected women, as their education level was lower on average (Ngo, 2002). It has also been argued that women were clustered within low-level occupations, and they were less likely to be employed in occupations that have any decision-making power (Jacka, 1990; Dong et. al 2004). This structure is likely to lead to differential worker productivity across genders, as workers with similar characteristics were not assigned to comparable jobs.

Privatization in China took place in both high technology and low technology industries. According to Bai et al. (2009), the highest percentage of privatization took place in medical and pharmaceutical products, a high technology industry, which was followed by two low technology industries, beverage production and textile production, which were then followed by another high technology industry, chemical production. While there has been no study for China that has examined the differential effect of privatization on female labor between high and low technology industries, increased competitive pressures are likely to induce firms to organize their labor in a more efficient manner. As a result, the compensation and productivity of female labor should differentially increase in the high technology industries, where they have comparative advantage. In addition, the wage-productivity gaps should narrow down as the industry moves towards a more competitive equilibrium, where workers receive the value of their marginal product.

This paper complements and extends the literature by examining how privatization has affected wage and productivity gaps differently in high and low technology industries. We specifically focus on China, where the manufacturing sector experienced technology upgrades along with a massive transformation from state-owned to private ownership. There is still little known about how compensation and the marginal product of workers have fared during this transformation. Given that female labor has a comparative advantage in high technology industries and a comparative disadvantage in low technology industries, competition due to privatization should increase their relative wages and productivity by more in the high technology industries. This straightforward intuition is somewhat complicated by differences in the initial structure of their gender outcomes, which we will discuss further below. This paper focuses on all state-owned firms in 1999 and follows them through the privatization process while distinguishing between the high and low technology industries. By doing this, we reveal evidence showing that privatization has reduced gender wage-productivity differentials within high technology industries, but has not lead to the same reduction in low technology industries. This result complements earlier work on the gender-specific effects of both privatization and technological improvements within the manufacturing sector.

3 Data and Descriptive Analysis

The data used in this paper is from the Chinese National Bureau of Statistics' Large-and-Medium Enterprise (LME) Survey. The information in this survey is obtained from the annual reports of almost all of the state-owned enterprises, as well as from the large and medium-sized, privately owned enterprises with sales above five million yuan (RMB). This is arguably the most comprehensive firm-level database for the Chinese manufacturing sector, as it covers all state-owned firms and all medium and large private in China, and accounts for 94 percent of the total industry output. The main analysis focuses on the years between 2004 and 2007, as the gender information is only available for these particular years. Following Bai et al. (2009), a panel data set is constructed from the 8,934 state-owned firms that appeared in all years and were wholly state-owned when they first entered the panel in 1999. These firms are then followed over time, and the privatized firms distinguished by their changed ownership status from state-owned to privately-owned since 1999. Among these firms, 3,079 were privatized, while 5,855 remained state-owned through the end of 2007.

High technology industries are defined using the OECD technology categorizations, which classify industries into four groups based on their research and development (R&D) intensity, as well as the amount of their R&D embodied in intermediate and investment goods (OECD, 2011).[3] Based on this classification, high technology manufacturing industries are defined as industries that produce goods embodying medium-high to high amounts of technology, such as electrical machinery, office machinery, transportation vehicles, telecommunication equipment, medical equipment, chemicals, and pharmaceuticals. The low-technology manufacturing industries consist of those industries that embody a low amount of technology, such as textiles, food products, wood and paper products, rubber and plastic products, basic metals and metal products, and other mineral products.

The firm characteristics for high and low technology firms are summarized in Table 1. In panel A, we focus on all firms that were state owned in 1999, and within this group, we distinguish between the firms that are later privatized, and firms that remained as state-owned in until 2007. This is done in order to compare

[3]This classification is presented in Table A.1.

the firms prior to privatization, and trace through how privatization balanced out the differences over time. In the main analysis, the sample of firms is selected based on their ownership status in 1999. Panel B presents the same comparison across low and high technology firms, as well as state-owned and privatized firms between 2004 and 2007. All variables in this panel are averaged across the whole period, with the exception of firm age which represents the average age of the firms as of 1999 in Panel A, and average age of the firms as of 2007 in Panel B.

In the initial year of 1999, the table shows that privatized firms were younger, they had higher output levels, and similar capital intensity, as compared to the firms that remained as state-owned. These relationships were largely maintained until the 2004-2007 period, with the exception of a weakly significant capital intensity difference within high technology firms. Lower average employment level and higher output level imply that labor tends to be relatively more productive among privatized firms. During the 2004-2007 period, the table shows that the employment level is substantially lower among privatized firms as compared with the state-owned firms.[4] The average employment in privatized firms was 160 and 68 workers were lower than state owned firms in high and low technology industries, respectively. Bai et al. (2009) argues that privatization was associated with lower firm level employment as labor surplus problem was prevalent in state-owned firms.

In terms of wage compensation, there are significant differences both across firm groups and over time. In low technology industries, privatized firms initially offered lower compensation, and the gap had widened over time from 9 percent in 1999 to 12 percent in the 2004-2007 period. On the other hand, in high technology industries, average wages in state-owned and privatized firms were initially equivalent (columns 1 and 2). By the 2004-2007 period, privatized firms on average paid 4 percent less than state-owned firms due to the slower wage increase over time. It can also be seen from the table that low technology industries are more capital intensive than high technology industries in both panels. This is due the fact that most capital intensive sectors are classified as low technology as they have relatively low R&D intensity, such as manufacturing of food, wood and paper products, while the definition of high tech industries includes sectors

[4]The data does not contain employment information in 1999.

that are skilled-worker intensive rather than capital intensive such as chemical and pharmaceuticals.

Table 2 presents the female share of employment over time. In high technology industries, approximately 30 percent of the workers are female and there are no significant differences between state-owned and privatized firms. On the other hand, the female share is significantly higher in privatized firms in low technology industries. In general, the female share in low technology industries is between 7 and 11 percentage points higher than it is in high technology industries. This is consistent with the findings of Gao et al. (2013), who used firm privatization as a within-industry labor demand shift. They reported that the increase in demand for the less educated was biased toward female workers, while the demand for the more educated was biased towards male workers. On the other hand, the supply of highly educated female workers had been increasing much faster than that of male workers, leading to larger wage gaps between the genders.

This increase in the share of female labor can help explain the overall wage differences across genders and the initial structure of labor prior to privatization would affect the direction of labor outcomes post-privatization. If initially the highly educated female workers is clustered in the state-owned firms in high technology industries, this may lead to an inefficient allocation of tasks, and thus low productivity among female workers. In this case, privatization should reduce the relative wages of female workers and increase their relative productivity to achieve an efficient equilibrium. At the same time, as was suggested by Liu et al. (2000), the market-oriented economic reforms in China affected job mobility as well as wages. By removing the equalizing shields of state ownership in industries in which female workers hold a comparative disadvantage, privatization could lead to a reallocation of tasks that would move female labor towards relatively less productive activities in these industries, putting downward pressure on their wages.

Table 1: Average Characteristics of All Firms that were State-Owned in 1999 by Technology Intensity

	A: 1999						**B. 2004-2007**					
	High Technology			Low Technology			High Technology			Low Technology		
	(1) SOE	(2) Privatized	(3) p-values	(4) SOE	(5) Privatized	(6) p-values	(7) SOE	(8) Privatized	(9) p-values	(10) SOE	(11) Privatized	(12) p-values
Employment	-	-		-		-	653.1	493.4	0.000***	942.6	874.5	0.028**
							[1378.1]	[878.8]		[2658.7]	[3984.6]	
Wages	2.144	2.184	0.303	2.281	2.186	0.000***	2.747	2.701	0.0201**	2.873	2.761	0.000***
	[0.747]	[0.681]		[0.689]	[0.689]		[0.676]	[0.579]		[0.717]	[0.610]	
Output	8.602	8.724	0.129	8.982	9.157	0.008***	9.026	9.226	0.000***	9.353	9.769	0.000***
	[1.554]	[1.312]		[1.913]	[1.552]		[1.833]	[1.458]		[2.136]	[1.638]	
Firm Age	3.653	3.539	0.000***	3.645	3.504	0.000***	3.609	3.135	0.000***	3.561	3.126	0.000***
	[0.455]	[0.504]		[0.479]	[0.526]		[0.484]	[0.727]		[0.534]	[0.729]	
Capital/Labor	3.677	3.678	0.985	3.867	3.824	0.2695	4.072	4.012	0.045*	4.282	4.298	0.487
	[1.066]	[1.095]		[1.081]	[1.017]		[1.183]	[1.072]		[1.198]	[1.092]	
Market Share	0.011	0.010	0.625	0.078	0.031	0.000***	0.068	0.057	0.310	0.227	0.199	0.225
	[0.037]	[0.031]		[0.442]	[0.097]		[0.471]	[0.294]		[1.301]	[1.120]	
N	737	615		1,561	1,304		3,084	2,593		6,182	5,315	

Notes: The sample contains all firms that were state-owned in 1999, and distinguishes the firms that were later privatized. Columns (1) to (6) presents average characteristics between 2004-2007, the study period. Columns (7) to (12) presents initial characteristics in 1999 when all firms were state-owned. The technology intensities are determined according to OECD (2011). Standard deviations are presented in brackets. The p-values of t-tests of the equivalence between privatized and state-owned firms are shown in columns (3), (6), (9) and (12). The variables are constructed as follows: Employment variable is not available in 1999, and defined as the firm-level number of workers in 2004-2007 period. Wages are the total wage bill divided by the number of employees, as defined in thousands of RMB, Output is measured as the value-added, and Firm Age indicates the age of the firm in 2007. The Capital/Labor ratio is defined as the fixed assets of the firm divided by its employment. Market Share is the ratio of a firms sales to the total 1-digit industry sales (x10^4). Wages, Output, Firm Age, and the Capital/Labor ratio are presented in log form. The number of firms for the 2004-2007 period shows the total number across four years. All of the dollar values are deflated using the CPI with 2004 as the base year.

Table 2: Share of Female Workers by Technology and Year

	High Technology				Low Technology			
	(1) All Firms	(2) State-Owned	(3) Privatized	(4) p-values	(5) All Firms	(6) State-Owned	(7) Privatized	(8) p-values
All Years	0.302	0.305	0.299	0.096*	0.388	0.372	0.405	0.000***
	[0.142]	[0.141]	[0.144]		[0.177]	[0.166]	[0.188]	
2004	0.301	0.305	0.297	0.283	0.387	0.373	0.404	0.000***
	[0.134]	[0.129]	[0.138]		[0.168]	[0.158]	[0.176]	
2005	0.304	0.308	0.298	0.193	0.388	0.373	0.406	0.000***
	[0.142]	[0.142]	[0.142]		[0.179]	[0.168]	[0.188]	
2006	0.302	0.306	0.298	0.285	0.386	0.372	0.403	0.000***
	[0.145]	[0.148]	[0.142]		[0.176]	[0.166]	[0.187]	
2007	0.302	0.302	0.303	0.918	0.389	0.372	0.408	0.000***
	[0.149]	[0.143]	[0.155]		[0.186]	[0.173]	[0.199]	
N	5,479	2,945	2,534		11,091	5,883	5,208	

Notes: Standard deviations are presented in brackets. The average share of female employment is presented in each cell. The p-values of t-tests of the equivalence between privatized and state-owned firms are shown in columns (4) and (8).

4 Methodology

The empirical methodology of this paper aims to determine whether the observed wage premium paid to workers reflects their productivity premium. Following Hellerstein and Neumark (1999) and Dong and Zang (2009), each manufacturing plant in year t is assumed to have a Cobb-Douglas production function, given by:

$$Q_t = A(E_t L_t)^{\alpha} K_t^{\beta} \tag{1}$$

where Q is the output, A is the productivity level, E_t is the average worker productivity, L_t is the amount of labor, and K_t is the amount of capital in year t. [5]

Suppose L_t^f and L_t^m are the number of female and male workers of the total labor force, where $L_t^f + L_t^m = L_t$. Also, denote the average productivity of female workers by q_t^f, and the average productivity of male workers by q_t^m. Then, the average worker productivity E_t can be written as the average productivities of female and male workers weighted by their employment shares:

$$E_t = q_t^m \frac{L_t^m}{L_t} + q_t^f \frac{L_t^f}{L_t} = q_t^m + (q_t^f - q_t^m)\frac{L_t^f}{L_t} \tag{2}$$

Rearranging the above expression and taking the natural logarithm yields:

$$ln(E_t) = ln(q_t^m) + ln\left[1 + (\rho_t - 1)\frac{L_t^f}{L_t}\right] \tag{3}$$

where ρ_t is the productivity ratio of male and female workers, q_t^f/q_t^m. If $\rho_t < 1$, then it implies that women are less productive than men in year t.

Assume that male and female workers are paid a wage of W_t^f and W_t^m in year t, respectively. Thus, the average wage of a firm in year t, W_t, is a weighted average of the wages of female and male workers. Similar to equation (3), the average wage paid by the firm can be written as:

[5] Hellerstein and Neumark (2007) and Van Biesebroeck (2011) show the results does not change when a translog production function, as a second order approximation, is used instead

$$lnW_t = ln(W_t^m) + ln\left[1 + (\phi_t - 1)\frac{L_t^f}{L_t}\right] \tag{4}$$

where ϕ_t is the wage ratio of female and male workers, W_t^f/W_t^m. If $\phi_t < 1$, then it implies that the wage of a female worker is lower than that of a male worker in year t. The linear approximation of $ln(W_t^m)$ and $lnA_t + ln(q_t^m)$ by various firm, industry, and regional variables, and re-arranging equations (3) and (4) yields the following empirical estimating equations:

$$ln(W_t) = \lambda_0 + ln\left[1 + (\phi_t - 1)\frac{L_t^f}{L_t}\right] + X_t'\lambda + u_t \tag{5}$$

$$ln(Q_t) = \gamma_0 + \alpha ln\left[1 + (\rho_t - 1)\frac{L_t^f}{L_t}\right] + \alpha ln(L_t) + \beta ln(K_t) + Z_t'\gamma + \nu_t \tag{6}$$

where $\phi_t = W_t^f/W_t^m$ and $\rho_t = q_t^f/q_t^m$, λ_0 and γ_0 are constant terms, and α and β are coefficients of the Cobb-Douglas production function for the effective labor and capital amounts, respectively. The vectors, X_t and Z_t, contain other firm characteristics. Following Dong and Zhang (2009), Hellerstein and Neumark (1998) and Rickne (2012), these vectors include firm age, market share, the capital-labor ratio and provincial fixed effects.[6] The firm subscript is omitted here for simplicity.

The two error terms, u_t and v_t, are likely to be correlated, as the unobservable factors that affect worker productivity could also affect wages. In order to incorporate the potential correlation between these error terms, it is assumed that u_t and v_t have a bivariate distribution with a correlation coefficient, ε. The above model can then be estimated using simultaneous nonlinear least squares for each year and pooling across all four years. This approach allows for the joint determination of wages and productivity levels, as well as a thorough examination of their changes over time.

The model compares wage differentials and productivity differentials between genders. If the female workers have comparative disadvantage and they are dis-

[6]This model was also separately estimated with firm level fixed effects. While this specification was unable to provide the standard errors due to the large number of firms, the point estimates were consistent with the results presented in this paper which instead controls for firm-level characteristics.

proportionately assigned to low wage and low productivity occupations, we expect both ϕ and ρ to be less than unity. In this case women who are paid less are also less productive, but the competitive equilibrium is maintained in the sense that workers are paid their value of their marginal product. In segregated labor markets where women are confined to low wage and low productivity occupations, the interpretation of the outcomes does not necessarily lead to Becker (1971) type of wage discrimination. The mechanisms that confine women into low wage and low productivity activities may include supply side factors, such as education, flexibility of hours, benefits, maternal leave or cultural norms about gender appropriateness of certain occupations, or demand side factors related to gender preference of the employer (Dong et al., 2004; Gao. et al. 2013).

Equivalency of relative wages and relative productivity levels is tested by comparing wage ratio ϕ_t, and the gender productivity ratio, ρ_t. The deviations form consistent wage and productivity ratios indicate that firms indulge in discriminatory behaviour across genders. In this case the test of the absence of gender discrimination can be written as $\phi_t = \rho_t$. Following the literature, this can be tested against the hypothesis that $\phi_t < \rho_t$, where there is gender discrimination against female workers, or $\phi_t > \rho_t$, where there is a wage premium being paid to female workers.[7]

5 Results

This model is estimated for manufacturing firms for the period from 2004 to 2007, while distinguishing between two firm ownership types, privately-owned and state-owned firms, and two industry types, low technology and high technology industries. Table 3 presents the results for state-owned and privatized firms, where the estimates are presented for the wage ratio, $\hat{\phi}$, the productivity ratio, $\hat{\rho}$, and the wage-productivity differentials, with each estimate is tested against the null hypothesis of no differentials.

The results for state-owned firms suggest that, the gender wage ratios are substantially higher in high technology industries when compared to low technology

[7]The inequalities can be referred to as 'gender inferior' and 'gender preferred'. In this paper, we follow the terminology that is commonly used in the literature.

industries. Female workers are paid approximately 83 percent of their male counterparts in high technology industries, on average, while this ratio was 62 percent for low technology industries. The higher returns to education of female workers relative to male workers reported in Zhang et al. (2005) can explain high wage ratios in the high technology sectors, as these sectors embody relatively more skilled workers. The estimates for the gender productivity ratios show that female productivity was 44 percent for state-owned firms in high technology sectors and 59 percent in low technology sectors. The test for no productivity differential, $\rho = 1$ is rejected at the 1 percent level for both industry types.[8]

The gender wage ratio is relatively higher than the gender productivity ratio indicating that lower wages of female workers were more than fully accounted for by their lower productivity. It also suggests that female workers were paid a wage premium in high technology sectors. The formal test for the wage-productivity differentials, $\phi - \rho = 0$, confirms that the gap was statistically significant for the high technology sectors. The gender wage premium in state-owned firms was also reported in Dong and Zhang (2009), however we show in this paper this was significant only in high technology industries. On the other hand, in the sectors that embody a relatively low amount of technology (column 2), the gender wage ratio was insignificantly different than productivity ratio.

The differentials between wage and productivity levels could indicate that state-owned firms reward female employees in order to achieve gender equality in the compensation, even though female employees are relatively less productive. This is an inefficient practice for a profit maximizing firm, and could not be maintained under perfect competition. The differentials could also be associated with frictions in the product market and labor market that prevent firms from allocate labor efficiently and produce at the optimal level (Hellerstein et al., 1999; Hellerstein and Neumark, 2005), or the mismatch between skills and tasks prior to labor market liberalization (Dong and Zhang, 2009).

[8]If the labor inputs are correlated to firm characteristics, then the estimates of gender wage and productivity ratios can be biased. Hellerstein and Neumark (1995) check this issue by imposing average values instead of estimating coefficients and found that results were no affected.

Table 3: Gender Wage-Productivity Differentials by Technology and Ownership Type

	State Owned		Privatized	
	High Technology (1)	Low Technology (2)	High Technology (3)	Low Technology (4)
Gender wage ratio: $\hat{\phi}$	0.833***	0.622***	0.722***	0.675***
	(0.068)	(0.032)	(0.055)	(0.026)
$H_0 : \phi = 1$	0.014**	0.000***	0.000***	0.000***
Gender productivity ratio: $\hat{\rho}$	0.439***	0.593***	0.446***	0.309**
	(0.131)	(0.094)	(0.114)	(0.057)
$H_0 : \rho = 1$	0.000***	0.000***	0.000***	0.000***
Gender wage-productivity differentials:				
$\hat{\phi} - \hat{\rho}$	0.394***	0.029	0.276**	0.366***
$H_0 : \phi - \rho = 0$	0.002	0.742	0.011	0.000
N	2,945	5,883	2,534	5,208
R^2 (Wage Equation)	0.250	0.329	0.290	0.344
R^2 (Productivity Equation)	0.649	0.697	0.618	0.658
Correlation of error terms: ε	0.340	0.415	0.341	0.340

Notes: Standard errors are presented in parenthesis. The coefficients of ϕ and ρ are obtained from simultaneous estimation of equations (5) and (6) using nonlinear least squares. p-values for the hypothesis tests are presented. Wage, employment, output and capital variables are defined as described in the model. The sample includes all firms that were state-owned in 1999, and distinguishes the firms that are privatized after 1999. OECD (2011) is used to define technology intensities. High technology includes firms in high and medium-high technology industries, and low technology includes firms in medium-low and low technology industries. All regressions controls firm-level characteristics including the capital-labor ratio, market share, firm age and provincial fixed effects. *** p<0.01, ** p<0.05, * p<0.1.

In privatized firms, the wage ratio is estimated to be 72 percent in high technology industries and 68 percent in low technology industries. The hypothesis of no wage differential was strongly rejected in both cases. Similarly, productivity ratios are estimated to be 45 percent and 31 percent for high and low technology industries, respectively, and both estimates were significantly different than unity. The difference between gender wage ratio and gender productivity ratio is statistically significant for both types of industries, while the magnitude was lower in high technology industries. The result of a lower wage-productivity differential in the high technology sector is consistent with the South Korean case, as reported by Ural et al. (2009).[9]

The impact of privatization on a gender productivity ratio is consistent with comparative advantages of female workers. That is, privatization was associated with an increase in the gender productivity ratio in high technology industries, and a reduction in low technology industries. The high technology industries are more likely to adopt computerized technologies that are less physically demanding, allowing more women to be employed in these occupations (Weinberg, 2000). It is also consistent with a segregation in the labor market where female workers are disproportionately represented in low productivity occupations and industries. This was prevalent in both state-owned and private firms in China where female labor were crowded into clerical or low-level administrative occupations (Ngo, 2002; Dong and Zhang, 2009).

The gender wage ratio has decreased in high technology industries. Because state owned firms had paid a premium to their female employees, the relative female wages have decreased until the competitive equilibrium is reached where the wage ratio is productivity ratio. Nevertheless, the gender premium still existed among privatized high technology firms.[10] We later look at the time-varying coefficients to see whether or not the gap between wage and productivity ratios are narrowing over time. On the other hand, in low technology industries, the gender

[9]We test the robustness of the results using Hecker (2005) technology classification, which was first developed by Bureau of Labor Statistics (BLS). The results are robust to this change. However, we believe the OECD (2011) classification is a better alternative for China as Hecker (2005) classification relies on United States data only.

[10]Ng (2006) showed that earnings premium for computer use in China accrues only to female workers, but not to male workers, which may explain persistent wage premia in high technology firms.

wage ratio is slightly higher among privatized firms. This is potentially due to very low initial relative wages for women and the pressure from regulatory institutions to achieve gender equality.

In low technology industries, the sharp reduction in the gender productivity ratio suggests that there are other factors that affect relative worker productivity. Previously, we have shown that the share female workers in low technology privatized firms is significantly higher when compared to the female share in high technology industries. This difference is insignificant among firms that remain as state-owned suggesting that low technology firms have increased the female share of employment upon privatization. The reduction in relative productivity implies that low technology industries are gender inferior. That is, privatization was associated with a disproportionate assignment of female workers to low productivity occupations (Ngo, 2002; Dong and Zhang, 2009; Liu et al. 2000).

Next, the model is estimated with time-varying coefficients in order to understand how gender wage and productivity differentials have evolved over time. Table 4 presents these results for state-owned firms. In three of the four years, the gender wage ratio was not significantly different than unity in high technology sectors. On the other hand, in low technology sectors relative wages of women were significantly lower than unity in all years. The evidence also shows that, while there is a slight reduction over time, the gender wage ratio has been largely stable among state-owned firms in both low and high technology industries. This is intuitive as the pay scales are less likely to change in state-owned firms.

The estimates for ρ show that the relative productivity was in fact consistent with relative wages in low technology industries. For example, in 2004, the wage ratio was 62.1 percent, the productivity ratio was 59.8 percent, and the difference between the two estimates was insignificant. The productivity ratio has decreased over time, while it remained consistent with relative wages across all years. This suggests that gender inferiority of low technology industries was also prevalent in state-owned sectors where female workers are progressively assigned to low productivity and low wage occupations. However, there is no evidence of Becker-type discrimination as relatively low wages can be explained by relatively low productivity levels of female workers.

Table 4: State-Owned Firms by Technology: Time-Varying Coefficients

	2004		2005		2006		2007	
	High Tech (1)	Low Tech (2)	High Tech (3)	Low Tech (4)	High Tech (5)	Low Tech (6)	High Tech (7)	Low Tech (8)
Gender wage ratio $\hat{\phi}$	0.877***	0.621***	0.854***	0.627***	0.740***	0.603***	0.841***	0.594***
	(0.144)	(0.064)	(0.130)	(0.064)	(0.116)	(0.060)	(0.144)	(0.059)
$H_0 : \phi = 1$	0.391	0.000***	0.261	0.000***	0.025**	0.000***	0.267	0.000***
Gender productivity ratio: $\hat{\rho}$	0.377	0.598***	0.317	0.725***	0.460**	0.541***	0.554	0.406***
	(0.258)	(0.175)	(0.187)	(0.214)	(0.217)	(0.170)	(0.395)	(0.145)
$H_0 : \rho = 1$	0.016**	0.022**	0.000***	0.197	0.013**	0.007***	0.259	0.000***
Gender Wage-Productivity Differentials:								
$\hat{\phi} - \hat{\rho}$	0.500	0.023	0.537	-0.098	0.280	0.062	0.287	0.188
$H_0 : \phi - \rho = 0$	0.041*	0.889	0.006***	0.616	0.204	0.700	0.439	0.162
N	763	1,515	754	1,506	749	1,498	679	1,364
R^2 (Wage Equation)	0.306	0.380	0.277	0.328	0.259	0.344	0.227	0.366
R^2 (Productivity Equation)	0.680	0.711	0.683	0.712	0.679	0.731	0.595	0.698
Correlation of error terms ε	0.376	0.372	0.301	0.425	0.245	0.347	0.348	0.385

Notes: Standard errors are presented in parenthesis. The coefficients of ϕ and ρ are obtained from simultaneous estimation of equations (5) and (6) using nonlinear least squares. p-values for the hypothesis tests are presented. Wage, employment, output and capital variables are defined as described in the model. The sample includes all firms that were state-owned in 1999, and distinguishes the firms that are privatized after 1999. OECD (2011) is used to define technology intensities. High technology includes firms in high and medium-high technology industries, and low technology includes firms in medium-low and low technology industries. All regressions controls firm-level characteristics including the capital-labor ratio, market share, firm age and provincial fixed effects. *** p<0.01, ** p<0.05, * p<0.1.

In high technology industries, the relative productivity levels of female workers have increased from 37.7 percent to 55.4 percent. Because relative wages declined and relative productivity increased, the gap between the two estimates have closed over time. The wage-productivity differentials were significant only in 2004 and 2005, when female workers were paid a wage premium ($\phi > \rho$). This means that state-owned firms in high technology industries have progressively removed the wage premium paid to female workers and moved towards a more competitive equilibrium.

The results for privatized firms are presented in Table 5. In high technology industries, the gender productivity ratio has declined over time. ρ was estimated to be 57.9 percent in 2004 and 40.7 percent in 2007, both statistically different than unity. While the level of productivity ratio was higher than that of state-owned firms, the downward trend shows that gender segregation is also taking place in high technology firms. This may be due to low supply of highly educated female workers, and the initial purge of increased female productivity due to privatization was not maintained over time. Consistent with the decline in relative productivity, relative wages also declined over time. High technology privatized firms remained at the competitive equilibrium as the wage ratio was not statistically different than productivity ratio, with the exception of 2006.

In contrast, both wage and productivity ratio displayed an upward trend in low technology industries. The productivity ratio is estimated to be 23.6 percent in 2004 and 39.7 percent in 2007, while the wage ratio is estimated as 63.7 percent in 2004 and 70.5 percent in 2007. The gender wage ratio and the gender productivity ratio in privatized low technology sectors was significantly different than unity in all years. This improvement suggests that the gender segregation is declining in low technology privatized firms, a trend that is not prevalent among firms that remained as state-owned. The wage-productivity differentials among these firms were significant at an equilibrium where female workers are paid a wage premium. This upward trend could be associated with higher ratio of foreign ownership among low technology industries. Foreign-owned firms tend to be more productive and employ higher share of female workers, thus increasing both relative productivity and relative wages. While they are increasing over time, the productivity ratio among privatized low technology firms is still much lower when

compared to the firms that remained as state-owned.

Finally, the theory suggests that the gap between relative wages and relative productivity levels should decrease over time as privatization increases competitive pressures. This can be seen in Table 5 where the magnitude of wage-productivity differentials has decreased from 0.28 to 0.14 for high tech firms, and from 0.40 to 0.31 for low technology firms. State-owned firms also experienced the competitive pressures and moved towards a competitive equilibrium, particularly in high technology industries where gender wage premiums were slowly eliminated.

The model is next estimated using a more disaggregated industry classification, where industries are divided into four groups according to their technology intensity: low technology, medium-low technology, medium-high technology and high technology.[11] Previously, we have found that state-owned firms paid wage premiums to female workers.The disaggregated results show that the gender wage premium was significant in medium-high technology firms, such as firms that produce machinery, motor vehicles, and chemicals, but not in firms with very high technology, such as for aircraft, computers, and radio and television manufacturing. At the other end of the technology intensity spectrum, the results suggest that the reduction in the gender productivity differential was especially driven by firms with very low technology intensity, such as for textiles, food products, and wood products.

[11]This classification was done according to what is presented in Table A.1

Table 5: Privatized Firms by Technology: Time-Varying Coefficients

	2004		2005		2006		2007	
	High Tech (1)	Low Tech (2)	High Tech (3)	Low Tech (4)	High Tech (5)	Low Tech (6)	High Tech (7)	Low Tech (8)
Gender wage ratio $\hat{\phi}$	0.863***	0.637***	0.808***	0.682***	0.616***	0.638***	0.552***	0.705***
	(0.124)	(0.055)	(0.111)	(0.048)	(0.095)	(0.047)	0.087	0.052
$H_0 : \phi = 1$	0.268	0.000***	0.085*	0.000***	0.000***	0.000***	0.000***	0.000***
Gender productivity ratio: $\hat{\rho}$	0.579**	0.236**	0.656**	0.293**	0.161	0.264**	0.407**	0.397***
	(0.261)	(0.094)	(0.264)	(0.119)	(0.126)	(0.105)	(0.204)	(0.116)
$H_0 : \rho = 1$	0.107	0.000***	0.193	0.000***	0.000***	0.000***	0.001***	0.000***
Gender Wage-Productivity Differentials:								
$\hat{\phi} - \hat{\rho}$	0.284	0.401	0.152	0.389	0.455	0.374	0.145	0.308
$\phi - \rho = 0$	0.271	0.000***	0.549	0.007***	0.001***	0.002***	0.462	0.006***
N	650	1,324	635	1,319	637	1,309	612	1,256
R^2 (Wage Equation)	0.350	0.364	0.330	0.384	0.309	0.391	0.298	0.319
R^2 (Productivity Equation)	0.635	0.683	0.630	0.673	0.617	0.656	0.658	0.672
Correlation of error terms ε	0.271	0.331	0.301	0.320	0.342	0.322	0.305	0.309

Notes: Standard errors are presented in parenthesis. The coefficients of ϕ and ρ are obtained from simultaneous estimation of equations (5) and (6) using nonlinear least squares. p-values for the hypothesis tests are presented. Wage, employment, output and capital variables are defined as described in the model. The sample includes all firms that were state-owned in 1999, and distinguishes the firms that are privatized after 1999. OECD (2011) is used to define technology intensities. High technology includes firms in high and medium-high technology industries, and low technology includes firms in medium-low and low technology industries. All regressions controls firm-level characteristics including the capital-labor ratio, market share, firm age and provincial fixed effects. *** p<0.01, ** p<0.05, * p<0.1.

Table 6: Gender Wage-Productivity Differentials by Disaggregated Technology Classification

	High-Tech		Medium-High Tech		Medium-Low Tech		Low Tech	
	State Owned	Privatized	State Owned	Privatized	State Owned	Privatized	State Owned	Privatized
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Gender wage ratio $\hat{\phi}$	0.760***	0.753***	0.875***	0.726***	0.860***	0.806***	0.545***	0.623***
	(0.132)	(0.113)	(0.077)	(0.060)	(0.068)	(0.053)	(0.037)	(0.031)
$H_0 : \phi = 1$	0.070*	0.029**	0.104	0.000***	0.041**	0.000***	0.000***	0.000***
Gender productivity ratio: $\hat{\rho}$	0.488**	0.297	0.392***	0.429***	0.405***	0.590***	0.654***	0.312***
	(0.238)	(0.247)	(0.130)	(0.117)	(0.126)	(0.160)	(0.123)	(0.067)
$H_0 : \rho = 1$	0.031**	0.004***	0.000***	0.000***	0.000***	0.007***	0.005***	0.000***
Gender Wage-Productivity Differentials:								
$\hat{\phi} - \hat{\rho}$	0.272	0.456	0.483	0.297	0.455	0.216	-0.109	0.311
$\phi - \rho = 0$	0.231	0.057*	0.000***	0.008***	0.000***	0.127	0.334	0.000***
N	624	532	2764	2397	2148	2392	3566	2626
R^2 (Wage Equation)	0.368	0.478	0.252	0.487	0.387	0.353	0.324	0.350
R^2 (Productivity Equation)	0.862	0.805	0.634	0.871	0.731	0.667	0.687	0.654
Correlation of error terms ε	0.365	0.321	0.338	0.346	0.400	0.368	0.427	0.335

Notes: Standard errors are presented in parenthesis. The coefficients of ϕ and ρ are obtained from simultaneous estimation of equations (5) and (6) using nonlinear least squares. p-values for the hypothesis tests are presented. Wage, employment, output and capital variables are defined as described in the model. The sample includes all firms that were state-owned in 1999, and distinguishes the firms that are privatized after 1999. OECD (2011) is used to define technology intensities. All regressions controls firm-level characteristics including the capital-labor ratio, market share, firm age and provincial fixed effects. *** p<0.01, ** p<0.05, * p<0.1.

6 Conclusion

This paper provides a firm-level investigation of the impact of privatization on the gender-specific wage and productivity outcomes in China. The analyses are based on a comprehensive, nationally representative survey of firms in China that covers ninety-four percent of all sales in the manufacturing sector. The paper takes advantage of the panel aspect of the survey by following all firms that were state-owned when they first entered the survey in 1999, and by distinguishing the firms that were later privatized.

The paper uses a methodology that estimates the worker productivity and wages directly from the firm's production function, and it identifies discrimination by comparing relative wages of female workers to their relative productivity levels. This approach circumvents the need to rely on workers' observable characteristics in the Mincer equation, which does not account for all of the gender-related productivity differences, leading to an overestimation of the unexplained portion of the wage gaps. In addition, this methodology allows us to determine whether the observed changes in the discrimination were because of the changes in wages, productivity levels, or both of these outcomes.

The evidence presented in this paper show that privatization impacted the relative productivity of female labor according to their comparative advantages. That is, the gender productivity ratio has increased in high technology industries and declined in more physically demanding low technology industries. However, the results suggest that this improvement in the relative productivity of female labor among privatized high technology firms may not be maintained over time as the firms face a relatively low supply of highly educated female labor force. Nevertheless, privatization induced competition and caused high technology industries move towards a more competitive equilibrium.

In low technology industries, the relative productivity of female labor tends to increase over time, while the magnitude of the gender wage ratio is still quite low. This highlights that productivity gains associated with privatization is taking place where female labor is clustered, potentially in foreign-owned firms in low technology industries. It also implies that gender segmentation in these industries is becoming less prevalent over time. While the results indicate improvement, the

gender productivity ratio is still very small in low technology industries, implying a disproportionate allocation of female labor in low productivity occupations within low technology industries. This may be associated with employer discrimination, as well as relatively human capital endowments of female workers.

The structural gender inequality in the Chinese labor market existed both under the centralized regime and after the market liberalization. Many scholars have argued that market reforms, especially the privatization of firms, has led to deterioration in relative outcomes of female labor. What has been largely overlooked in this literature is that the impacts depend on the complementarity between female labor and production technology of firms. Market forces tend to induce higher relative productivity of female labor in high technology industries, while reducing it in low technology industries. In competitive markets, relative compensation will eventually reflect the relative productivity of female workers. Therefore, it is imperative to improve female enrollment in higher education, thus increase female share in high technology industries, in order to achieve greater gender equality in the labor market.

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A Appendix

Table A.1: Classification of Industries with respect to Technology Intensity

Classification	Industries
High Technology	Aircraft and Spacecraft
	Pharmaceuticals
	Office, accounting and computing machinery
	Radio, TV and communications equipment
	Medical, precision and optical instruments
Medium-high technology	Electrical machinery and apparatus, n.e.c.
	Motor vehicles, trailers and semi-trailers
	Chemicals excluding pharmaceuticals
	Railroad equipment and transport equipment, n.e.c.
	Machinery and equipment, n.e.c.
Medium-low technology	Building and repairing of ships and boats
	Rubber and plastics products
	Coke, refined petroleum products and nuclear fuel
	Other non-metallic mineral products
	Basic metals and fabricated metal products
Low technology	Manufacturing, n.e.c.; Recycling
	Wood, pulp, paper, paper products, printing and publishing
	Food products, beverages and tobacco
	Textiles, textile products, leather and footwear

Source: Organisation for Economic Co-operation and Development (2011). Classification is based on R&D intensity and R&D embodied in intermediate and investment goods.

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