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Environmental regulation and wages in China

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In this study we examine the extent to which firms pass back the cost of pollution regulation to workers, in the form of lower wages, using a unique matched employer-employee dataset for Shanghai. The benefits and costs of pollution regulation in China are important topics to study as China comes under increasing pressure to move from a single-minded focus on energy-driven economic growth to a more balanced approach to economic growth. The benefits of such a shift, particularly in terms of health, are relatively well studied, but the costs are less so. The hip-pocket effect of pollution regulation on workers' wages is particularly important, given that it is likely to influence public support for a more balanced approach. Our main finding is that the reduction in average wages attributable to firms taking measures to control for pollution is between 13.8% and 18.8%, all things being equal.

Keywords: wages; pollution abatement; China

1. Introduction

China has had one of the highest rates of economic growth among developing countries for a period spanning three decades. However, China has been heavily dependent on dirty-burning coal to fuel its high rate of economic growth. It has been the world's largest consumer of coal since 1986, the second largest consumer of electricity since 1995 and the second largest consumer of oil since 2002 (BP 2009). However, China's energy efficiency remains relatively low (Ma *et al*. 2009). As a result, China's carbon dioxide emissions have increased dramatically in recent times, such that China is now the second largest gas emitter in the world (Auffhammer and Carson 2008). The high energy consuming industries in China produce the majority of industrial air pollution (Cole *et al*. 2008a). As a consequence, China has been described as 'choking on its own success' (Kahn and Yardley 2007). In response to concerns about poor air quality and environmental degradation, there is some evidence that the Chinese Government is reconsidering the costs of an unfettered emphasis on economic growth. Environmental protection is a cornerstone of China's commitment to more balanced economic growth, reflected in the Hu-Wen notion of a 'harmonious society'. China's industrial firms are coming under increasing pressure to curb pollution emissions.

A series of theoretical studies have examined the backward incidence of pollution control (Yohe 1979, Yu and Yu 1982, Forster 1984, Wang 1990). These studies

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suggest that expenditure on pollution abatement is a cost of production that shifts the supply curve to the left. Moreover, firms which spend on pollution abatement will, whenever possible, pass the cost on to workers in the form of lower demand for labour and/or lower wages. This paper examines the backward incidence of pollution abatement on wages, using a unique matched employer-employee dataset collected from Shanghai. Specifically, the paper addresses the following question: who bears the cost of pollution abatement and to what extent do firms pass the cost of pollution abatement back to labour in the form of lower wages?

This question is important to address in the Chinese context because China's strategy of growing rapidly through burning coal has been a major reason for the rapid growth in urban incomes. Rapid industrial growth has literally lifted tens of millions of people out of poverty. If the Chinese Government is going to adopt a more balanced approach to economic growth, it is important to be aware of the potential costs to labour in terms of lower wages. A more balanced growth path has been lauded because of its positive effect on urban living standards and the health of the urban populace via reduced pollution levels (Li *et al*. 2004, World Bank 2007). However, to the extent that the costs of pollution abatement are passed on to workers in the form of lower wages, there is also a potential adverse effect on living standards. The effect on the hip pocket is also likely to influence the extent to which China's urban workers support a more balanced approach to economic growth. If the cost in terms of lower wages is too high, support for balanced growth policies are likely to wane.

2. Chinese context

China has experienced annual GDP growth of 10% per annum over an extended period. Its energy consumption has expanded, both in terms of volume and growth rate, to facilitate its high rate of economic growth. Its primary energy consumption was 2002.5 million tonnes oil equivalent in 2008, with annual growth of 16.8% over the period 2002–2008 (BP 2009). China is now the largest consumer of energy products.

China's energy consumption has generated pollution on a large scale. It is the largest coal producer in the world and coal is the major source of energy in China, constituting approximately 75% of all energy sources. Coal contributes 90% of China's sulphur dioxide emissions and approximately 70% of its total dust, nitrogen oxide and carbon dioxide emissions (Zhang 2007). It has twice the sulphur dioxide emissions of the United States, with some estimates suggesting that in the future these emissions will be up to five times their current level. According to the World Bank (2007) China has 16 of the world's 20 most polluted cities. In 2005, only 31% of Chinese cities met national air quality standards, and more than 75% of water in rivers in China's urban areas could not be used for drinking or fishing (Economy 2007). The World Bank (2007) estimated that only 1% of China's urban population of 560 million breathe air that is considered safe in the European Union.

The World Bank (2007) estimated that the health costs of air and water pollution amount to 4.3% of GDP and the non-health impacts to 1.5% of GDP, making the total cost of air and water pollution in China 5.8% of GDP. According to World Bank estimates from the 1990s, the number of annual pollution related premature deaths in China from a mixture of outdoor air pollution in large cities, indoor air pollution from inhaling fumes from coal-burning stoves and cooking oil as well as

cancers and diarrhoea from drinking polluted water, were approximately 400,000 (Toy 2007). In a preliminary version of the World Bank's (2007) most recent study on pollution in China, it is estimated that the annual number of premature pollution-related deaths in China is as high as 750,000. While this figure was censored from the final version of the World Bank (2007) report, it was openly discussed at the conference launching the World Bank study and has been reported in the media (see e.g. Kahn and Yardley 2007, Toy 2007). China's air pollution is also responsible for a high prevalence of asthma (Watts 2006) and cardiovascular disease (Kan *et al.* 2009) in Chinese cities.

As part of the Chinese Government's commitment to more balanced growth, under the Hu-Wen administration, the State Environmental Protection Authority (SEPA) of China has been elevated to full ministerial status. This has empowered SEPA to push for more stringent implementation and monitoring of environmental regulations. As a result, SEPA has had some success in halting projects that have not undertaken proper environmental impact assessments (Zhang 2007). This said, one problem with environmental regulation in China is that, while the central government and SEPA profess a commitment to environmental protection, these regulations are not always fully enforced at the local level. This is because, at the local level, officials are rewarded on the basis of meeting GDP targets that do not take account of environmental degradation. In 2004, for the first and only time, the Chinese Government reported figures for Green GDP, which adjusted GDP to reflect the cost of pollution. The figures, however, were sobering, with the pollution-adjusted growth rates in several provinces being close to zero. The idea of reporting Green GDP in China has since been shelved because of strong opposition from local government officials (Kahn and Yardley 2007). Local officials were opposed to Green GDP as a concept from the start because lower adjusted growth rates reduce their prospects for promotion (Economy 2006).

However, while local officials are sometimes reluctant to monitor environmental regulations, China has a nascent environmental civil society movement. Since the mid−1990s approximately 3000 environment oriented non-government organisations (NGOs) have been established in China. These organisations, such as the well-known 'Friends of Nature' and 'Global Village of Beijing', primarily focus on raising awareness and hands-on environmental activism (Martens 2006). Citizen complaints about the environment, expressed on official 'hotlines' and in letters to local officials, are increasing at 30% per annum and were expected to top 450,000 in 2007 (Economy 2007). There are also an increasing number of political demonstrations complaining about the environment. Economy (2007) mentioned one such demonstration in 2005 when 30,000 to 40,000 people in Zhejiang province vandalised 13 chemical plants as part of a protest about air pollution. The Chinese central government provides tacit support for this environmental movement as a means of scrutinising environmental protection at the local level, although no criticism of the central government's policies are permissible (Martens 2006, Mol and Carter 2006, Larson, 2007).

The data in this study are from Shanghai. Shanghai is one of China's most populous and prosperous cities. Situated on the estuary of Yangtze River, facing the East China Sea, in 2005 the city had a permanent population of 13.8 million people and 5.8 million rural-urban migrants (SBS 2006). Energy use and pollution problems in Shanghai are similar to those in China as a whole. Coal accounts for approximately 70% of the city's total energy consumption. Air and water pollution

is severe in Shanghai (Chen and Yao 2008) and is associated with several adverse health effects (Fang 1989, Chen 1994). In a series of simulation studies for Shanghai, Li *et al*. (2004) found the health benefits from pollution reduction would be substantial, relative to the direct cost of the investment needed for such initiatives. Similar to other cities in China, firms in Shanghai are subject to a mix of formal and informal pollution regulation. Following Cole *et al*. (2008a), we define formal regulations as those imposed by SEPA or local authorities ('government regulation'). Wang (2002) and Wang and Wheeler (1999) provide detailed discussions of such measures. In contrast to formal regulations, informal regulation occurs when communities, or China's civil environmental protection movement, regulate firms through lobbying and petitioning ('self-regulation').

3. Existing literature

This study is related to several strands of literature. One series of studies computed willingness to pay for clean air, based on wage differentials across cities (see e.g. Cropper and Arriaga-Salinas 1980). A second series examined whether there is a wage premium for working in pollution intensive industries (Cole *et al*. 2009). A third series analysed the extent to which firms shift the burden of mandated social security obligations, or payroll taxes, back on to workers in the form of lower wages (Holmund 1983, Gruber and Krueger 1991, Gruber 1994, 1997). A fourth series considered the effect of pollution abatement on labour productivity (see e.g. Christiansen and Haveman 1981).

Few studies have directly examined the effect of pollution abatement on the demand for labour or wages. As Morgenstern *et al*. (2002) and Cole and Elliott (2007) noted, there are several avenues through which the demand for labour could be influenced by the stringency of environmental regulations. First, environmental regulations may increase production costs that, in turn, increase output prices, reduce final demand and hence the demand for labour. Second, alternatively as environmental regulations increase production costs, more inputs will be needed to produce the same amount of output, which will have a positive effect on the demand for labour. Third, the actual process of abating pollution and the post-abatement production equilibrium may be more or less labour intensive than the pre-abatement production, which could result in a positive or negative effect on labour demand.

Berman and Bui (2001) examined the impact of new air quality regulations on employment in the affected industries in Los Angeles, introduced between 1979 and 1992. These authors found that these regulations did not, in fact, reduce the demand for labour in Los Angeles, but may have increased it. Morgenstern *et al*. (2002) similarly found that environmental regulations had a small positive effect on labour demand in the US. Shadbegian (2005) examined the impact of air quality regulations on employment in US manufacturing as a whole, using panel data, during the period 1974 to 1985 and found that environmental regulation significantly reduced the demand for production workers and non-production workers. Henderson (1996) and Kahn (1997) also found employment growth in US manufacturing to be lower in those industries subject to more stringent environmental regulations. Hollenbeck (1979) employed a computable general equilibrium model to analyse the effect of restrictions on levels of permissible emissions from stationary sources set by the 1970 Clean Air Act Amendments in the US. He found that the Act Amendments had a

regressive effect on earnings. Cole and Elliott (2007) examined the effect of environmental regulations on the demand for labour in the UK, and found that environmental regulation costs had no statistically significant effect on employment.

Among related studies for China, China's energy consumption and its relationship with economic growth has been extensively analysed (see Ma *et al*. 2010 for a survey). Cole *et al*. (2008a) studied the determinants of industrial pollution in China. Wang and Wheeler (1999) and Wang (2002) examined the impact of pollution regulation on abatement expenditure for Chinese industrial polluters and found that abatement expenditures are responsive to pollution regulation. Several studies have tested the pollution haven hypothesis (PHH) (He 2006, Dean *et al*. 2009, Lin *et al*. 2011). Smyth *et al*. (2008) examined the impact of pollution on subjective well-being across 30 Chinese cities, while Zhai and Suzuki (2008) examined willingness to pay for environmental quality in Tianjin. None of these studies, however, are concerned with wages. In the spirit of the third set of related studies mentioned above, Nielsen and Smyth (2008) examined the effect of compliance with social insurance obligations on wages in Shanghai. That study found that employers who complied with social security obligations in Shanghai passed on part of the cost to workers in the form of lower wages. However, these authors did not consider the effect of pollution abatement on wages. To summarise, there are few empirical studies that have considered the relationship between pollution abatement and either the demand for labour or wages of workers; and there are no studies that do so using Chinese data.

4. Data

We use a matched worker-firm dataset from Minhang district in Shanghai collected by the Chinese Academy of Social Sciences (CASS) in 2007. The dataset, which contains information on 784 employees from 78 firms, was selected by Probability Proportion to Size sampling according to a list of all manufacturing firms in Minhang district whose annual sales were at least 5 million RMB. Once missing data were removed, we had valid data for all the variables of interest in the study for approximately 600 employees and 69 firms. Table 1 gives descriptive statistics for the firms in a sample and compares them with descriptive statistics for firms in Minhang District and Shanghai as a whole. The statistics in Table 1 suggest that the sample is generally representative of firms in Minhang District and Shanghai.

Table 2 presents descriptive statistics for the employees in the sample, based on whether the respondent worked for a firm that reported undertaking measures to control pollution. These pollution measures could be the result of either government regulation or self-regulation. Of the 41 firms that had introduced measures to control

Table 1. Representativeness of the sample.

	Sample	Minhang District	Shanghai
Number of employees (person)	182.82	202.83	190.38
Sales revenue (10 thousand RMB)	8896.69	11974.22	12445.22
Profits (10,000 RMB)	675.27	800.10	866.94
Average wage of employees (RMB/month)	2145.55	2383.42	2423.25

Source: The data for Minhang District and Shanghai are from SBS (2008).

Table 2. Descriptive statistics for the sample.

Variable	Does firm take measures to control pollution?		
	No	Yes	Overall
Hourly wage[a] (based on employee survey)	11.15	9.74	10.11
Hourly wage[b] (based on firm survey)	8.99	8.01	8.41
Years of schooling	11.72	11.22	11.35
Experience	14.76	17.11	16.49
Male (%)	45.32	56.80	53.83
Married (%)	75.37	74.48	74.71
Speak Mandarin well (%)	71.78	61.79	64.37
Good health (%)	76.85	79.18	78.57
Urban Hukou (%)	55.45	56.72	56.39
Member of Communist Party (%)	4.43	12.85	10.65
Member of trade union (%)	34.72	37.82	37.01
Occupation (%)			
Professional/technician	25.76	20.66	22.01
Producer/transporter	24.75	23.58	23.89
Service worker	17.17	15.17	15.70
Equipment operator	32.32	40.59	38.39
Professional certification (%)			
No title	79.50	78.16	78.51
Elementary certification	13.00	14.38	14.03
Junior/senior certification	7.50	7.45	7.46
Ownership form of firm (%)			
State/collective owned firm	–	11.88	8.80
Share holding/public firm	24.63	34.25	31.76
Foreign/Taiwan/HK JV firm	60.10	33.22	40.18
Private firms	15.27	20.65	19.26
Number of respondents	203	581	784
Number of firms	28	41	69

[a]Difference statistically significant with a p-value of 0.01. [b]Difference statistically significant with a p-value of 0.03

for pollution, 14 did so in response to government regulation and 27 as an act of self-regulation. Table 2 reports both the gross hourly wage rate (including bonuses) for employees in the sample and for all employees in the firms that were surveyed. The gross average hourly wage rate of surveyed workers is slightly higher than the gross average hourly wage rate of all workers in the firms surveyed. However, for both the employees in the sample and for all employees in the surveyed firms, wages in firms that reported undertaking measures to control pollution were statistically lower than in firms which reported taking no measures to control pollution. This gives some initial support for the notion that firms subject to government or self-regulation on pollution pass the costs on to workers. In the wage equations, reported below, while we are primarily interested in the effect of pollution abatement on wages, we also control for a range of characteristics of the worker. Descriptive statistics for these variables, based on whether or not the firm reported undertaking measures to control pollution, are given in Table 2.

Of note from Table 2 is that, overall, 60% of firms which responded that they did not take measures to control for pollution were either foreign firms or firms from Hong Kong or Taiwan. Whether foreign firms are cleaner than domestic firms, and

whether foreign firms are more or less likely to adopt pollution abatement measures, is an empirical issue. If heavier polluters are more likely to adopt abatement measures, the fact that 60% of firms which do not adopt abatement measures are foreign firms might suggest that foreign firms in the sample are cleaner. There are, however, competing hypotheses about the motives of foreign firms investing in developing countries, which consequently might explain why foreign firms do, or do not, adopt abatement measures. According to the PHH, developed economies tend to have strict environmental regulations that will drive up firms' production costs. To save costs, pollution-intensive firms may relocate themselves to developing countries that have less stringent environmental regulations (Walter 1982). If the foreign firms in the sample are motivated to invest in China because of China's relatively less stringent environmental standards, this would explain why a high proportion of foreign firms have not taken abatement measures. An alternative hypothesis is the trade-up hypothesis (TUH), which states there is a 'pollution halo' around foreign firms. According to the TUH, foreign firms are less pollution intensive than their domestic counterparts because they may utilise more advanced technologies, use cleaner production methods and need to meet the expectations of more environmentally conscious consumers in export markets in developed countries (Cole *et al*. 2011). If foreign firms are cleaner, this is an alternative explanation for why foreign firms contribute disproportionally to the number of firms not adopting abatement measures.

Empirical support for the competing hypotheses in the wider literature is mixed. Some studies have found support for the PHH (Cole and Elliott 2005, MacDermott 2009, Wagner and Timmins 2009), while other studies have found no support for the PHH (Eskeland and Harrison 2003, Javorcik and Wei 2004). Studies which have found support for the TUH include Eskeland and Harrison (2003) and Cole *et al*. (2008b). Evidence on the PHH and TUH for foreign investment in China is similarly mixed. Dean *et al*. (2009) found that support for the PHH in China depended on the investor's source country and the pollution intensity of the industry, with support for the PHH limited to investors from low-income countries investing in pollution intensive industries. Cole *et al*. (2011) found that the share of foreign-owned firms in China increased several pollutants in a statistically significant manner, while output of firms from Hong Kong, Macau and Taiwan either reduced pollution or had no statistically significant effect. These authors attribute these results to the pollution intensity of the industry in which foreign firms, and Hong Kong, Macau and Taiwan firms, are concentrated. Lin *et al*. (2011) tested the PHH and TUH using data from Shanghai and found support for the TUH; namely, foreign firms emitted less pollution and were more likely to comply with environmental regulations than domestic firms with no international linkages. Hence, even if foreign firms are less likely to undertake abatement, what this says about whether they are cleaner than domestic firms, and their motives, is not clear.

The findings of Cole *et al*. (2011) that firms from Hong Kong, Macau and Taiwan were lower pollution emitters, because of the industries in which they are located, provides a partial explanation for why 60% of those firms that reported not taking abatement measures were foreign firms in this study. Foreign firms actually consist of firms from Hong Kong and Taiwan and firms from elsewhere. The majority of those foreign firms that reported not taking abatement measures were, in fact, from Greater China, rather than elsewhere, which probably reflects the fact they are located in less pollution-intensive industries.

5. Empirical specification and methodology

We employ a Mincer (1974) earnings function, in which gross hourly wage earnings including bonuses (measured in RMB) is regressed on years of schooling, post-school experience, post-school experience squared, a dummy variable for whether the firm reported undertaking measures to control pollution and a series of control variables. The specific control variables that we employ are gender, marital status, health, household registration status, language ability, whether the individual is a member of the Communist Party, the size of the firm for which the individual works, proxied by the log of the number of employees, and dummy variables for professional certification, occupation and ownership form of the firm.

If firms pass the cost of pollution abatement on to workers we can expect a negative relationship between pollution abatement and wages. There is, however, also potentially a compensating wage differential argument here. Cole *et al*. (2009) argued that workers would demand higher wages for working in a dirty firm. These authors found that wages are higher in firms in dirty sectors. Using UK data, they found a small wage premium of approximately one-quarter of 1% associated with working in a dirty sector, which rises to over 15% for those individuals working in one of the five dirtiest sectors. If workers demand higher wages in high polluting firms, we might also expect that wages would be higher in pollution abating firms, suggesting a positive relationship between pollution abatement and wages. The reasoning is that firms which control for pollution may be cleaner than those that do not *ex post*, but the results could potentially reflect that non-pollution control firms are in fact cleaner to begin with, given that firms in the dirtiest sectors are the firms that are most likely to abate.

Turning to the other variables, based on human capital theory, wages are determined by investment in human capital. Schooling and on-the-job training are major types of investment. Thus, we expect a positive relationship between years of schooling and wages. Post-school experience is a proxy for job-training investment. We expect the wage-experience profile to follow a parabolic shape in experience. Wages will initially increase, reach their peak when human capital is at a maximum, and eventually fall as human capital depreciation dominates accumulation.

Of the control variables, we expect that individuals with better self-reported health will have higher productivity and earn higher wages. We expect that individuals with urban household registration will earn more, given that previous studies report evidence of labour market discrimination against migrants, who typically have a non-urban household registration (see e.g. Liu 2005). We expect that being a member of the Communist Party will command a wage premium. Previous studies have found that Communist Party members earn more than non-Communist Party members in the Chinese urban labour market (see e.g. Appleton *et al*. 2005, Li 2003, Bishop and Liu 2008). There are two possible explanations. One is that a wage premium for Communist Party members could simply be economic rents for a privileged group. A second explanation is that the Party can be viewed in much the same fashion as a college in Western countries, as a screen for talent, motivation and other personal characteristics correlated with productivity (Bishop and Liu 2008). The expected sign on marital status is *ex ante* unclear. Individuals who are married might, in a time allocation sense, have less time available for work tasks because of family commitments. However, marriage can also generate efficiencies through specialisation and the division of labour, where tasks are divided between spouses,

freeing up time (Baker and Jacobsen 2007). Language proficiency is a form of human capital. We expect that individuals with a better command of Mandarin will earn higher wages. We expect that males will earn more than females, given widespread evidence of gender discrimination in earnings in Chinese urban labour markets (Zhang 2007). A number of studies have suggested that firm size and wages are positively correlated (Oi and Idson 1999). However, previous research suggests that in China larger firms, in fact, pay lower wages. The reason for this is that large firms in China employ a disproportionate number of blue collar workers (Gao and Smyth 2011).

Regressions are estimated using ordinary least squares (OLS) with White heteroskedastic-consistent standard errors. Whether the firm undertakes measures to control pollution is potentially endogenous, because it will depend on the state of its capital stock, level of technological knowledge and investment in clean technologies. The Durbin-Wu-Hausman test (augmented regression tests) for endogeneity was performed. This is a test for endogeneity in a regression estimated via instrumental variables (IV). The null hypothesis states that an OLS estimator of the same equation would yield consistent estimates; that is, any endogeneity among the regressors would not have adverse effects on the OLS estimates. A rejection of the null hypothesis indicates endogeneity and that IV techniques are required. The relevant explanatory variable was 'whether or not the firm takes measures to control pollution (voluntarily or through government regulation)'. This variable is a dummy variable that takes a value of 1 if the firm takes pollution control measures and zero otherwise. We employed three IVs for 'whether or not the firm takes measures to control pollution':

- How many times did the firm update its production technology in the previous year?
- How many years have the machines in this firm been used, on average?
- How much did the firm spend on research and development in the previous year?

Each of these three variables can be expected to be correlated with whether a firm takes measures to control for pollution. A firm updating its technology frequently will have cleaner technology and thus lower levels of pollution. A firm replacing its machines more frequently will have more recent capital stock and thus lower levels of pollution. A firm spending more on research and development is likely to have cleaner technology and lower levels of pollution. However, each variable is unlikely to be directly correlated with wages. Using these three IVs for 'whether or not the firm takes measures to control pollution', we conducted the IV regression and computed the Durbin-Wu-Hausman test statistics. We failed to reject the null hypothesis of exogeneity at the 5% level, suggesting that the OLS estimator would yield consistent estimates and we do not need IV techniques.

A potential problem with the OLS estimates of the earnings function is the omission of an individual's ability, which may bias the OLS estimates of returns to schooling. The OLS estimator has two ability biases relative to the average marginal return to education: one attributable to the correlation between schooling and the intercept of the earnings function, the other attributable to the correlation between schooling and the slope of the earnings function (see Card 1999 for a review of the literature focused on ability biases). OLS may overestimate returns to schooling due

to positive correlation between schooling and ability. Alternatively, OLS estimates may underestimate rates of return to education, due to heterogeneity among individuals in returns to schooling. Angrist and Krueger (1991) suggested that the quarter of birth could be used as an IV. Given that our dataset did not contain any more common instruments for education, such as parent's education or spouse's education, we used the quarter of birth to instrument for educational attainment. We implemented the IV regression and computed the Durbin-Wu-Hausman test statistics. We failed to reject the null hypothesis of exogeneity at the 5% level, indicating that the OLS estimator gives consistent estimates for schooling.

6. Results

Table 3 presents the results of the Mincer (1974) earnings function. We present four alternative specifications in which different combinations of the dummy variables for certification, occupation, ownership and position are included. In the fourth specification in Table 3, dummy variables for each of certification, occupation, ownership and position are included. The results suggest that, depending on the specification, for those individuals surveyed, hourly wages were between 1.4 RMB per hour and 1.9 RMB per hour lower in firms which reported implementing measures to control pollution. For those who have a 48-hour working week, which is the official working week in China, this amounts to between 67.2 RMB and 91.2 RMB per week. For those who work a 60-hour week, which is the official working week plus the maximum overtime allowed by law, this equates to between 84 RMB and 114 RMB per week. Given that the average hourly wage for surveyed individuals was 10.1 RMB per hour, the results imply between a 13.8% and 18.8% reduction in the average hourly wage for those individuals in firms which reported implementing measures to control pollution. These results are consistent with abating firms passing on the costs of abatement to workers in the form of lower wages, rather than the existence of a compensating wage differential where workers in high polluting firms (which are more likely to undertake abatement) demand higher wages.

Of the other variables, for each additional 1% in the number of employees, the hourly wage is about 1 RMB lower (approximately 1% lower). Each additional year of schooling equates to an additional 1–1.1 RMB per hour. Males earn 2–2.4 RMB per hour higher than females. There is a wage premium for being married and being a member of the Communist Party. Married individuals earn 1.5–1.6 RMB per hour more than those who are single, while Communist Party members earn 1.8–2.1 RMB per hour more than those who are not members of the Communist Party. To put the cost to workers of firms implementing pollution controls in perspective, based on the upper bound estimate of 1.9 RMB per hour in specification 4, the returns for working in a firm which does not implement measures to control pollution, relative to one that does, is approximately equivalent to the returns for being a member of the Communist Party (1.8–2.1 RMB per hour), or two additional years of schooling (2–2.2 RMB per hour). Specification 4 in Table 3 contains dummy variables for ownership, certification, occupation and position. The ownership and position dummies were jointly significant as a group.

We also have information on the industry in which the firm is located. Table 4 presents the mean hourly wage across different industrial sectors, depending upon whether or not the firm takes any pollution control measures. Of the industries that

Table 3. Determinants of hourly wages of respondents.

VARIABLES	(1)	(2)	(3)	(4)
Firm takes measures to control pollution	−1.611**	−1.386**	−1.425**	−1.924***
	(−2.449)	(−2.070)	(−2.111)	(−2.806)
Ln (firm size)	−0.903***	−1.013***	−1.031***	−0.951***
	(−3.202)	(−3.534)	(−3.570)	(−3.211)
Education	1.141***	1.104***	1.069***	0.962***
	(8.378)	(8.073)	(7.563)	(6.355)
Experience	0.130	0.142	0.132	0.118
	(1.239)	(1.351)	(1.250)	(1.095)
Experience^2	−0.00321	−0.00327	−0.00310	−0.00330
	(−1.402)	(−1.431)	(−1.352)	(−1.417)
Male	2.261***	2.374***	2.315***	2.043***
	(3.810)	(3.992)	(3.859)	(3.219)
Married	1.466*	1.586*	1.556*	1.641*
	(1.715)	(1.855)	(1.815)	(1.875)
Good health	−0.459	−0.486	−0.479	−0.338
	(−1.197)	(−1.259)	(−1.232)	(−0.851)
Speaks Mandarin well	−0.135	−0.184	−0.213	−0.191
	(−0.195)	(−0.266)	(−0.305)	(−0.271)
Communist Party member	2.104**	2.120**	2.043**	1.777*
	(2.176)	(2.187)	(2.066)	(1.747)
Urban Hukou	0.187	0.134	0.131	0.436
	(0.264)	(0.190)	(0.184)	(0.597)
Member of Trade Union	−0.0217	0.225	0.213	0.0440
	(−0.0345)	(0.348)	(0.325)	(0.0649)
Ownership dummies?	NO	YES	YES	YES$^{\#}$
Certification dummies?	NO	NO	YES	YES
Occupation dummies?	NO	NO	NO	YES
Position dummies?	NO	NO	NO	YES$^{\#}$
Constant	0.172	0.140	0.877	2.876
	(0.0678)	(0.0514)	(0.316)	(0.935)
Observations	605	605	602	569
R-squared	0.229	0.237	0.240	0.303

Notes: Numbers in parenthesis are t-values. *** (**) (*) denotes significance at 10% (5%) (1%). # indicates the joint significance of dummies as a group. Ownership dummies are dummy variables for the ownership of the firm (state/collective-owned, shareholding/public. Foreign/Taiwan/HK joint venture or private). Position dummies are dummy variables for the position of the employee (production worker, technician, intermediate manager or high-level manager). Occupation dummies are dummy variables for the occupation of the employee (professional/technician, producer/transporter, service worker or equipment operator). Certification dummies are dummy variables for whether the employee has professional certification (no title, elementary certification or junior/senior certification). See Table 2 for descriptive statistics.

are listed in Table 4, the sample does not contain any firms that controlled for pollution in the following industries:

- Processing of food from agricultural products
- Manufacture of clothing textiles, footwear and caps
- Printing, reproduction of recording media
- Manufacture of rubber
- Manufacture of non-metallic mineral products
- Smelting and pressing of ferrous metals

Table 4. Average hourly wage rate of respondents across industries (RMB).

Industry	Average hourly wage (firm does not control for pollution)	Average hourly wage (firm does control for pollution)
Processing of food from agricultural products	10.27	–
Manufacture of foods	25.02	8.74
Manufacture of textiles	9.14	8.28
Manufacture of clothing textiles, footwear and caps	9.06	–
Manufacture of furniture	12.01	9.26
Manufacture of paper and paper products	7.58	8.18
Printing, reproduction of recording media	10.69	–
Manufacture of raw chemical materials and chemical products	5.65	8.28
Manufacture of rubber	10.04	–
Manufacture of plastics	8.45	8.86
Manufacture of non-metallic mineral products	12.08	–
Smelting and pressing of ferrous metals	12.72	–
Smelting and pressing of non-ferrous metals	10.78	–
Manufacture of metal products	11.66	7.98
Manufacture of general purpose machinery	13.72	–
Manufacture of special purpose machinery	8.89	9.63
Manufacture of transport equipment	6.57	–
Manufacture of electrical machinery and equipment	11.13	11.27
Manufacture of communication equipment, computers and other electrical equipment	12.65	11.69
Recycling and disposal of waste	10.15	–

- Smelting and pressing of non-ferrous metals
- Manufacture of general purpose machinery
- Manufacture of transport equipment
- Recycling and disposal of waste

Such industries account for 211 out of 784 data-points. Among the remaining industries, in most of the cases the firms which control for pollution pay lower wages to their workers compared to the firms which do not control pollution. However, in three industries (manufacture of raw chemical materials and chemical products, manufacture of plastics and manufacture of special purpose machinery) firms which control for pollution pay higher average wages to their workers than the firms which do not control pollution. A possible explanation is that in some highly specialised, perhaps skill intensive, industries in order to reduce pollution the firm needs to hire more skilled workers and pays them higher wages. Another possible explanation is that the higher wages in the chemicals and plastics industries could be due to pressure from workers to be compensated for the additional risk that they have to take in such sectors, which is consistent with the compensating wage differential argument made by Cole *et al.* (2009).

We also ran the full model (specification 4 of Table 3) with industry dummies. In a separate specification we removed the 211 data points for the industries in which

no firm controlled for pollution. The results of both the specifications are given in Table 5. Including industry dummies does not make any quantitative difference to the results in Table 3. From Table 4 it can be seen that the average hourly wage rate of firms in the food manufacturing industry, for those firms which do not control for pollution, are much higher than in other industries. To ensure the results in Table 5 are not sensitive to the inclusion of this industry, we dropped the outlier firms from this industry (firms reporting wages in excess of 50 RMB per hour, which were skewing the average to the right). The results from Table 5, without these outlier firms, are reported in Table 6. The results for the pollution variable are quantitatively the same as Table 5. Thus, the results reported in Table 5 are not sensitive to the inclusion of outliers.

Table 5. Determinants of hourly wages of respondents with industry dummies.

Variables	All firms	Removing the industries in which no firm controlled for pollution
Firm takes measures to control pollution	−1.531**	−1.354*
	(−2.033)	(−1.797)
Ln (firm size)	−1.201***	−1.587***
	(−3.664)	(−4.435)
Education	0.782***	0.885***
	(5.132)	(5.163)
Experience	0.0137	−0.0628
	(0.129)	(−0.526)
Experience^2	−0.00114	0.000410
	(−0.499)	(0.161)
Male	1.859***	1.748**
	(2.955)	(2.484)
Married	1.814**	2.118**
	(2.117)	(2.172)
Good health	−0.158	−0.470
	(−0.405)	(−1.064)
Speaks Mandarin well	0.0741	−0.197
	(0.106)	(−0.248)
Communist Party member	2.398**	2.313*
	(2.400)	(1.847)
Urban Hukou	0.394	0.133
	(0.545)	(0.162)
Member of Trade Union	0.936	0.556
	(1.379)	(0.738)
Ownership dummies?	YES	YES
Certification dummies?	YES	YES
Occupation dummies?	YES	YES
Position dummies?	YES	YES
Industry dummies?	YES	YES
Constant	4.427	3.170
	(1.127)	(0.772)
R-squared	0.389	0.412

Notes: Numbers in parenthesis are t-values. *** (**) (*) denotes significance at 10% (5%) (1%). For definition of ownership, occupation, certification and position dummies see Table 3. For industries included in the industry dummies see Table 4.

Table 6. Determinants of hourly wages of respondents with industry dummies after removing outlier firms from food manufacturing industry.

Variables	All firms	Removing the industries in which no firm controlled for pollution
Firm takes measures to control pollution	−1.244*	−1.126*
	(−1.803)	(−1.689)
Ln (firm size)	−0.887***	−1.230***
	(−2.938)	(−3.860)
Education	0.609***	0.666***
	(4.335)	(4.345)
Experience	0.0139	−0.0685
	(0.143)	(−0.648)
Experience^2	−0.00140	0.000231
	(−0.670)	(0.102)
Male	1.632***	1.468**
	(2.822)	(2.345)
Married	1.730**	2.017**
	(2.198)	(2.325)
Good health	−0.341	−0.674*
	(−0.953)	(−1.719)
Speaks Mandarin well	0.129	−0.149
	(0.200)	(−0.211)
Communist Party member	2.348**	2.185**
	(2.566)	(1.971)
Urban Hukou	0.723	0.543
	(1.090)	(0.743)
Member of Trade Union	0.770	0.392
	(1.240)	(0.588)
Ownership dummies?	YES	YES
Certification dummies?	YES	YES
Occupation dummies?	YES	YES
Position dummies?	YES	YES
Industry dummies?	YES	YES
Constant	5.385	9.244***
	(1.496)	(2.593)
R-squared	0.377	0.394

Notes: Numbers in parenthesis are t-values. *** (**) (*) denotes significance at 10% (5%)(1%). For definition of ownership, occupation, certification and position dummies see Table 3. For industries included in the industry dummies see Table 4.

Finally, we interacted the dummy variable for whether the firm controlled for pollution with a number of respondent characteristics; namely, whether the respondent speaks standard Mandarin, is a member of the Communist Party, is a member of a trade union and had an urban *hukou*. The objective was to examine whether different types of workers may be more or less susceptible to backward shifting of abatement costs. For example, it might be expected that in highly unionised firms there would be less opportunity to shift abatement costs back to workers. The interaction terms, however, were statistically insignificant in each case.

It is also possible that the amount of backward shifting of abatement could differ by type of firm (e.g. industry and size). When we interacted the dummy variable for

whether the firm controlled for pollution with firm size, the interaction term was insignificant. To examine whether backward shifting of abatement differed by industry, we collapsed the industries in Table 4 into five broad industry categories,

Table 7. Determinants of hourly wages of respondents (alternative specifications with interaction terms of industry dummies and pollution variable).

Variables	(1)	(2)	(3)	(4)	(5)
Firm takes measures to control pollution	−1.912*** (−2.731)	−1.597** (−2.246)	−2.044*** (−2.956)	−2.143*** (−2.874)	−1.937*** (−2.769)
Ln (firm size)	−0.951*** (−3.207)	−0.951*** (−3.217)	−0.891*** (−2.970)	−0.966*** (−3.252)	−0.952*** (−3.209)
Education	0.961*** (6.325)	0.947*** (6.258)	0.948*** (6.245)	0.954*** (6.281)	0.962*** (6.349)
Experience	0.119 (1.097)	0.118 (1.095)	0.118 (1.098)	0.124 (1.147)	0.118 (1.093)
Experience^2	−0.00333 (−1.417)	−0.00321 (−1.377)	−0.00328 (−1.406)	−0.00344 (−1.470)	−0.00330 (−1.412)
Male	2.039*** (3.202)	1.995*** (3.145)	1.988*** (3.126)	2.006*** (3.149)	2.046*** (3.217)
Married	1.634* (1.858)	1.615* (1.848)	1.674* (1.913)	1.549* (1.752)	1.646* (1.876)
Good health	−0.336 (−0.842)	−0.305 (−0.769)	−0.338 (−0.851)	−0.304 (−0.761)	−0.339 (−0.853)
Speaks Mandarin well	−0.192 (−0.273)	−0.183 (−0.260)	−0.158 (−0.224)	−0.244 (−0.345)	−0.185 (−0.261)
Communist Party member	1.779* (1.747)	1.692* (1.664)	1.660 (1.628)	1.803* (1.772)	1.776* (1.745)
Urban Hukou	0.438 (0.600)	0.418 (0.573)	0.573 (0.777)	0.399 (0.544)	0.435 (0.595)
Member of Trade Union	0.0428 (0.0630)	0.0293 (0.0433)	0.133 (0.195)	0.0317 (0.0467)	0.0387 (0.0568)
Pollution control X textile Dummy	−0.100 (−0.0875)				
Pollution control X chemical dummy		−1.320* (−1.695)			
Pollution control X metal dummy			1.500 (1.288)		
Pollution control X machinery dummy				0.540 (0.748)	
Pollution control X other dummy					0.0896 (0.0965)
Ownership dummies?	YES	YES	YES	YES	YES
Certification dummies?	YES	YES	YES	YES	YES
Occupation dummies?	YES	YES	YES	YES	YES
Position dummies?	YES	YES	YES	YES	YES
Constant	2.868 (0.931)	2.884 (0.939)	2.199 (0.705)	3.112 (1.006)	2.871 (0.932)
Observations	569	569	569	569	569
R-squared	0.303	0.306	0.305	0.304	0.303

Notes: Numbers in parenthesis are t-values. *** (**) (*) denotes significance at 10% (5%) (1%). For definition of dummy variables see Tables 3 and 4.

Table 8. Determinants of average hourly wage in the surveyed firms.

Variables	(1)	(2)	(3)
Firm takes measures to control pollution	−0.987*	−1.096*	−1.136*
	(−1.802)	(−1.855)	(−1.852)
Ln (firm size)		0.497	0.408
		(1.555)	(1.220)
Proportion of female employees		−1.323	−1.384
		(−0.906)	(−0.873)
Profit/sales ratio		2.300	2.468
		(0.921)	(0.966)
Ratio of blue collar workers		−3.325*	−3.465*
		(−1.894)	(−1.914)
Ownership dummies	NO	NO	YES
Constant	8.997***	9.897***	10.82***
	(21.32)	(6.258)	(5.230)
Observations	69	61	61
R-squared	0.046	0.151	0.174

Notes: Numbers in parenthesis are t-values. *** (**) (*) denotes significance at 10% (5%) (1%).

which were: chemical, rubber and plastics (200 observations); machinery (271 observations); metals and minerals (70 observations); textiles and fur (101 observations); and others (70 observations). The results when we interacted the dummy variable for whether the firm controlled for pollution, with each of the five broad industry categories, are reported in Table 7. The only interaction term which is statistically significant is for the chemical industry. For those individuals surveyed, hourly wages were 1.6 RMB per hour lower in firms which reported implementing measures to control pollution in non-chemical industries, compared with 2.9 RMB per hour lower in firms which reported implementing measures to control pollution in the chemical industry.

As a robust check on the pollution abatement variable in Table 3, Table 8 examines the effect of implementing measures to control for pollution on the average hourly wage rate in the firm, using data at the firm level. Specifically, we regress the average hourly wage in the firm on a dummy variable denoting whether the firm implemented measures to control for pollution, the log of firm size, the proportion of female workers in the firm, the ratio of blue collar workers in the firm, the profit to sales ratio in the firm and ownership dummy variables. The results suggest that, depending on the specification, the average hourly wage for all workers in the firm is between 1 RMB per hour and 1.1 RMB per hour lower in firms which reported implementing measures to control pollution. Given that the average hourly wage across firms in the sample was 8.4 RMB per hour, this equates to between 9.2% and 11.9%, which is similar to the lower bound estimate of 13.8% from the Mincer equation.

7. Conclusion

In spite of several theoretical studies suggesting that firms will pass the cost of pollution regulation back to workers in the form of lower demand for labour or lower wages, there is little empirical evidence on the backward incidence of pollution regulation. This is particularly true for the effect of pollution regulation on wages.

The reason for the lack of empirical evidence is probably the relative scarcity of matched employer-employee data which also contains information on whether the firm implements measures to control for pollution. In this study we have examined the extent to which firms pass back the cost of pollution regulation to workers in the form of lower wages, using a unique matched employer-employee dataset for Shanghai. The benefits and costs of pollution regulation in China are important topics to study as China moves from an unfettered focus on energy-driven economic growth to a more balanced approach. The benefits of such a shift, particularly in terms of health, are relatively well studied, but the costs are less so. The hip-pocket effect of pollution regulation on workers' wages is particularly important, given that it is likely to influence support for a more balanced approach among the urban populace. Our main finding is that in those firms which undertake measures to control for pollution, whether it be as a result of government regulation or self-regulation, the reduction in average hourly wages attributable to controlling for pollution is between 13.8% and 18.8%, all things being equal.

The study has some limitations that could be addressed in future research. First, while Shanghai is a major Chinese city that is, in many ways, representative of other major cities in China in terms of its energy use and pollution problems, our data is for a single city. Future research is needed for other cities in China including, where possible, multiple cities in the one study. Second, our dataset is cross-sectional. It would be interesting to examine the effect of pollution regulation on wages over time, using panel data. Third, we have measured pollution abatement using a dummy variable denoting whether the firm implemented measures to control pollution. Future studies could potentially use actual expenditure on pollution, which is likely to provide more precise estimates.

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