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Environmental Policy, Firm Dynamics and Wage Inequality in Developing Countries

By* CHI-CHUR CHAO, MONG SHAN EE, XIANGBO LIU, AND EDEN S. H. YU

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Abstract

This paper examines the short- and long-run effects of pollution taxes on wage gap, social welfare and the environment of a developing economy. Due to free entry of firms, the urban manufacturing sector tends to be over expanded with severe production-generated pollution emissions, which harm consumers. Urban firms can either abate the emissions or pay pollution taxes to emit. In the short run with a fixed number of firms, a rise in the pollution tax has an ambiguous effect of the skilled-unskilled wage gap, depending on the capital substituting and capital releasing effects of urban firms. Nonetheless, in the long run, the higher pollution tax can cause urban firms to exit. Capital is then released to the rural sector and benefits the production of rural workers, when the firm-exit effect is strong. This prediction is empirically validated. The higher pollution tax can therefore yield a double dividend in the long run by not only reducing pollution emissions but also narrowing skilled-unskilled wage gap in the economy.

JEL classification: O18, Q52, Q56

Keywords: Environmental tax, firm exit, wage inequality, developing economies

* Chi-Chur Chao, Department of Economics, Faculty of Business and Law, Deakin University, Australia. Mong Shan Ee, Department of Finance, Faculty of Business and Law, Deakin University, Australia. Xiangbo Liu, IMI, Renmin University of China, Beijing, China. Eden S. H. Yu, College of Business, Chu Hai College of Higher Education, Hong Kong.

1. Introduction

Economic growth has been a priority in policy design and implementation in many developing economies. The growth target may, however, harm the country's environment via consumption- and production-generated pollution emissions. The remarkable economic growth experienced in developing countries driven largely by a rapid expansion in production and consumption consequently can result in the speedy deterioration of the environment. The serious pollution currently experienced in China and Hong Kong are two vivid examples. China's air quality has been deteriorating since 2000 and getting worse from year to year. In 2013, the urban air pollution became so severe that 71 out of 74 cities monitored by the Chinese's Ministry of Environmental Protection failed to meet the safe air quality standard recommended by the World Health Organization's (WHO). Likewise, the air quality in Hong Kong had deteriorated to its worst level in nearly a decade, and Hong Kong Environmental Protection Department has warned the public that the poor air quality in a total of 177 days out of a year posed a high risk to health.

The exposure to excessive amount of pollutants released by motor vehicles, such as nitrogen oxide and ozone, along with other primary pollutants produced by fossil fuels combustion and industry emissions, like sulfur dioxide, has caused a large number of premature deaths and substantial monetary losses worldwide. It is estimated that air pollution in China claimed between 350,000 and 500,000 lives prematurely each year (Moore, 2014). In addition, Hong Kong air pollution caused more than 3,000 premature deaths and an estimated the monetary loss of HK$39 billion in 2012 (Lai, 2013).

To combat the air pollution caused in particular by consumption-generated emissions, both Chinese and Hong Kong governments have implemented various measures and policies to curb pollution emissions. These measures include the traffic restrictions implemented by the local municipality of major cities in China, including Beijing, such as the odd-even car plate restrictions by Beijing municipality, to reduce the number of cars on the road (Luo, 2014), and the incentive scheme to help vehicle owners to fit old diesel vehicles with particulate reduction devices and the reduction of first-time registration tax for environment-friendly vehicles launched by the Hong Kong government. In addition, as a measure to reduce the severe air pollution problem in big cities, firms located near Beijing have been ordered to move their production facilities to a new location which is far from the city. A notable one is the reallocation of the Shijiazhuang Iron and Steel Co, a subsidiary of China's largest steelmaker, to about 70 kilometres away from its old site by the end of 2017 to reduce severe air pollution in Beijing. This company has steelmaking capacity of 2.6 million tons a year and has been emitting sulfur dioxide, nitrogen oxide, dust and smoke for nearly 60 years. The authority expects this relocation will reduce the emissions of smoke and dust, which will help improve Beijing's air quality. Other nearby steel plants, such as Bohai Group in Tangshan and Jinan Steel Group and Taihang Steel Group in Handan, have also been ordered to move from city centres to costal or special industrial zones by 2017.[1]

Although the measures to curb consumption-generated emissions have been introduced and implemented, policies on industrial emissions through production have remained veiled in China and other Asian economies.[2] Recently, a draft on pollution fees was released on the basis of the user's pay principle that companies

[1] See a report, entitled "Steel Plants Told to Relocate" by Zhang Yu and Wang Wei in *China Daily*, January 18, 2016.

[2] See a report on China's pollution fees in *China Daily*, August 29, 2016.

and individuals who directly discharge pollution emissions would be subject to taxation and fine. Although this plan is expected to yield an estimated 22.8 billion to 45.7 billion yuan in annual tax revenue, the effects on emission reductions and related impacts to the economy have yet been discussed and examined.

The purpose of this paper is to fill in this gap. The main contribution of this paper is to investigate the effects of environmental controls and regulations on the economy and environment from production-side consideration. Specifically, we pay attention to firm dynamics, where favorable development policies together with lax environmental policy can make the number of urban firms in the industry to be excessive in developing economies. This causes severe production-generated pollution emissions, which harm consumers in those economies. Urban firms can then either abate emissions or pay pollution taxes to pollute. In the short run with a fixed number of urban firms, we find that an increase in pollution taxes can narrow or widen the wage gap depending on the capital substituting and capital releasing effects on urban firms. However, in the long run, the higher pollution tax on producers could cause firms to exit from the urban manufacturing sector. Capital is then released to the rural sector and can in turn benefit the production of rural workers, when the firm-exit effect is sufficiently strong. The higher pollution tax can therefore yield a double dividend in the long run by not only reducing pollution emissions, but also narrowing wage inequality between skilled and unskilled labor for the developing economy. The theoretical predictions obtained are then empirically validated. Using a sample of 37 low- and middle-income countries (including China), we provide empirical evidence to support the predictions derived in the theoretical model regarding both the short- and long-run effects of environmental regulations (or pollution tax) on income inequality. Our results show that income inequality can be reduced by at least 3.5% when firm-exit effect is taken into account.

This paper is organized as follows. Section 2 sets up a general-equilibrium model for a dual developing economy, in which environmental taxes are imposed on urban manufacturing firms for pollution emissions. Section 3 examines the short- and long-run effects of an increase in pollution taxes on income distribution and social welfare of the economy. Section 4presents the empirical methodology and discusses the regressions results. Section 5 concludes.

2. The model

We consider a developing economy with a dual structure of production: a manufacturing good X is produced by n firms in the urban sector and the agricultural commodity Y is produced in the rural sector. During the production process of the manufacturing good X, pollutants are however emitted as by-products. Urban manufacturing firms can either abate the pollution emissions or pay pollution taxes to emit. Choosing good Y as the *numeraire*, the relative price of the manufacturing good X is denoted by p and the tax on pollution emissions is t.

The developing economy exports the agricultural commodity Y under the given world price, while the manufacturing good X is non-traded. Domestic consumers demand for both manufacturing and agricultural goods by D_X and D_Y, and the utility function takes the form of quasi-linear preference as $U(D_X, D_Y) = D_Y + u(D_X) = D_Y + D_X - D_X^2/2$.Utility maximization, subject to the budget constraint, $I = pD_X + D_Y$, yields the (inverse) demand function for the manufacturing good X: $p = 1 - D_X$ which gives $p_X(= \partial p/\partial D_X) = -1$, where I denotes income. The indirect utility function of domestic consumers is thus given by: $V = V(p, I) = I - (1 - p)^2/2$, with $V_p = - D_X$ and $V_I = 1$ by the envelope theorem. For the goods-market equilibrium, domestic demand for the manufacturing good X is equal to its supply in the home economy, i.e., $D_X = X$. Note that there are n manufacturing firms in the urban sector, by imposing a symmetry condition, we have $X = nx$, where x denotes the output per manufacturing firm.

On the supply side of the economy, by combining unskilled labor (L_Y) and capital (K_Y),the rural sector produces agricultural commodity Y with a constant-returns-to-scale production function: $Y = Y(L_Y, K_Y)$. The corresponding unit cost of producing good Y is given by g (w_R, r), where w_R denotes the wage rate for rural unskilled labor and r is the rental rate for capital. The demands for unskilled labor and capital in the rural sector are respectively expressed by: $L_Y = g_w(w_R, r)Y$ and $K_Y = g_r(w_R, r)Y$, where the subscript represents the partial derivative. Assuming that the agricultural good market is perfectly competitive, in equilibrium zero profit prevails:

$$g(w_R, r)= 1, \tag{1}$$

where the price of the agricultural good Y is normalized to unity.

In the urban sector, under fixed equipment, management and supervision, manufacturing firms produce good X by employing unskilled production labor and physical capital. The production technology is under increasing returns to scale, with fixed cost, $f(w_S, r)$, and marginal costs, $m(w_U, r)$. The former comes from wage payment to nonproduction skilled labor and rental cost to capital, while the latter is associated with the payments to urban production unskilled labor and capital. Note that w_S denotes the wage rate for skilled labor in the economy and w_U is the wage rate for unskilled labor in the urban sector. Total cost for a urban manufacturing firm to produce quantity x is therefore: $c(w_S, w_U, r, x) = f(w_S, r) + m(w_U, r)x$. By utilizing the envelope property, the employments of skilled and unskilled labor for each individual firm in the urban sector are given by$s_x = f_w(w_S, r)$ and$l_x = m_w(w_U, r)x$, and the use of capital is represented by$k_x = f_r(w_S, r) + m_r(w_U, r)x$.

In the process of production, manufacturing firms in the urban sector generate pollution emissions, which harm consumers. The pollutants generated by a firm are directly linked to the output as a by-product. Firm can either abate pollution emissions or pay a pollution tax to emit pollutants. Note that abating emissions can be either carried out internally by the firms or outsourced externally to abating firms. Assuming that the abatement technology is to use domestic skilled labor and foreign equipment/technology, the unit cost of abatements is expressed by$\alpha(w_S, r^*)$, where r^* is the given rental rate of foreign equipment/technology. In equilibrium, analogous to the no-arbitrage condition, the unit abatement cost must be equal to the pollution tax rate:

$$\alpha(w_S, r^*) = t, \tag{2}$$

withα_w expresses the requirement of skilled labor for per unit pollution abatement. Consequently, pollution emissions of individual firm is $z = x – a$, where a denotes the amount of emissions abated.

In the urban sector, the after-tax profit of urban firm is therefore given by: $\pi = p(X)x – c(w_U, w_S, r, x)\text{-}\alpha(w_S, r^*)a–t(x – a) = p(X)x – c(w_U, w_S, r, x)\text{-}\ tx$. By choosing firm output, profit maximization yields the equality of marginal revenue to marginal cost:

$$p(X) + p_x(X)x= m(w_U, r) + t. \tag{3}$$

Note that Cournot quantity competition between urban firms is used in deriving this first-order profit-maximization condition.

Turn next to the factor markets. Following Harris and Todaro (1970), the dual developing economy is unevenly developed: the modern urban manufacturing sector is more advanced compared to the traditional rural sector. In the urban sector, an institutionally minimum wage rate, w_U, is set for unskilled labor, which is above the market-determined rural wage rate, w_R, for unskilled labor. This leads to unemployment (L_U) in the urban sector. Moreover, the higher urban wage rate attracts rural workers to migrate to the urban sector, but with a probability of $1/(1 + \mu)$ to be employed, where μ (= L_U/L_X) signifies the ratio of urban unemployment by noticing that L_X is the total employment in the urban sector (i.e., $L_X = nl_x$).Therefore, labor migration from the rural to the urban sector stops until the expected urban wage rate equals the rural wage rate:

$$w_U/(1 + \mu) = w_R. \tag{4}$$

This equation is known as the Harris-Todaro (H-T) migration equilibrium.

For the factor markets, the market-clearing conditions of unskilled labor, capital and skilled labor in the home economy are required by

$$(1 + \mu)m_w(w_U, r)nx + g_w(w_R, r)Y = L, \tag{5}$$

$$n[f_r(w_S, r) + m_r(w_U, r)x] + g_r(w_R, r)Y= K, \tag{6}$$

$$f_w(w_S, r)n + \alpha_w(w_S, r^*)na = S, \tag{7}$$

where L, K and S represent respectively the exogenous supplies of unskilled labor, capital and skilled labor in the economy. Note that in (7), full employment is assumed to prevail in the market of skilled labor, which determines its wage rate w_S, with $w_s > w_U > w_R$.

Finally, to complete the setup of the model, the number of urban manufacturing firms n needs to be considered: it is fixed in the short run, while urban firms can freely enter or exit in the long run until zero profit reaches:

$$p(X)x - f(w_S, r) - m(w_U, r)x - \alpha(w_S, r^*)a - t(x - a) = 0. \tag{8}$$

The model specified in (1) – (8) describes the dual structure of a developing economy, in which (1) – (7) determine seven unknowns, w_R, w_S, r, μ, x, Y and a in the short run with a fixed number of urban firms n, while in the long run the number of urban firms n is endogenously determined by the free entry/exit condition described in (8). The policy variable in the model is the pollution tax rate t on the urban manufacturing firms that emit pollution emissions. We will use this framework to examine the short- and long-run impacts of the changes in the pollution tax on factor returns, social welfare and the environment of the developing economy.

3. Pollution tax, wage inequality and social welfare

We begin with a study on the environmental regulation, say, a rise in the pollution tax, on factor returns and then to social welfare for the short and long runs. In the developing economy, capital tends to be located in the urban sector due to favorable development policies, including lax environmental regulations, to urban firms.[3] Thiscan result in less capital located in the rural sector, causing low wages for unskilled labor in the rural sector. The relationship between the capital rental rate and the unskilled wage rate in the rural sector can be seen from (1). By totally differentiating (1), we have:

$$\hat{w}_R = - (\theta_{KY}/\theta_{LY})\hat{r}, \tag{9}$$

where θ_{jY} represents the cost share of the jth production factor in producing good Y.[4] That is, under the given price of the agricultural good Y, to maintain the constant unit cost of production, a change in the capital rental rate r would yield an opposite effect on the unskilled wage rate w_R in the rural sector. This relationship on factor returns r and w_R is represented by a curve in the southwest quadrant in Figure 1.

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[3] See Restuccia and Rogerson (2013) for misallocation of capital in the economy.
[4] See Jones (1965) for the notation.

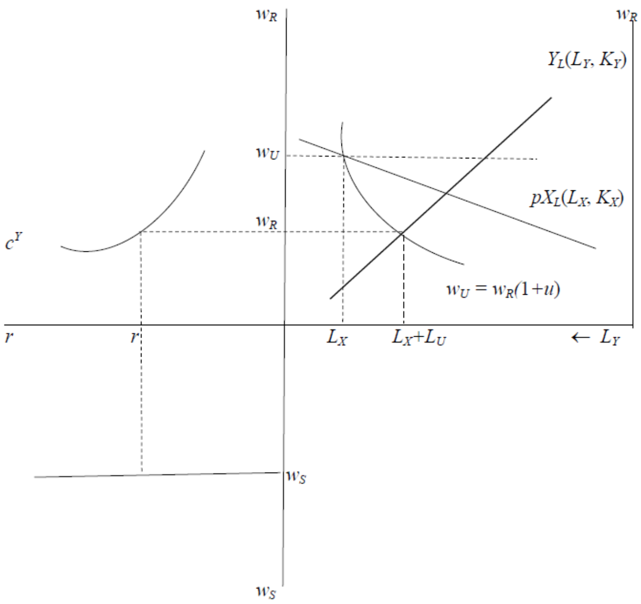

Figure 1. Labor market equilibrium

Note that by using $\mu = L_U/L_X$, the H-T migration equilibrium in (3) between the rural and the urban sector can be rewritten as $w_U L_X = w_R(L_X + L_U)$, which is depicted by a rectangular hyperbola in the northeast quadrant of Figure 1.[5] Since the minimum wage rate (w_u) for urban unskilled labor is institutionally fixed, a change in the rural unskilled wage rate affects labor migration and hence the ratio of urban unemployment μ. From (3), we have:

$$\hat{\mu} = - [(1 + \mu)/\mu]\, \hat{w}_R \, . \qquad (10)$$

This suggests that an increase in the rural wage rate lowers the urban unemployment ratio.

On the other hand, due to the given foreign rental rate r^* in (2), the change in the skilled wage rate depends entirely on the price of the abatements, which is equal to the tax rate of pollution emissions. By differentiating (2), we obtain:

$$\hat{w}_S = \hat{t}/\theta_{SA}, \qquad (11)$$

where θ_{SA} is the cost share of skilled labor in abating pollution emissions. As indicated in the southeastern quadrant of Figure 1, the skilled wage rate w_S can be expressed by a horizontal line, which will be shifted downwards when a stringent regulation, such as a rise in the pollution tax on emissions, takes place.

To obtain the overall impacts of the pollution tax on factor returns, the output effect is also needed to be considered. By totally differentiating (3), the change in firm output x in the urban sector is:

$$- (1 + 1/n)\hat{x} = \hat{n} + \varepsilon b\, \theta_{KX}^{m}\, \hat{r} + \varepsilon\tau\hat{t} \qquad (12)$$

where $b = m/p$ and $\tau = t/p$. Note that $\varepsilon = -p/p_x X$ signifies the price elasticity of demand for good X and θ_{jX}^{m} represents the variable cost share of factor j in producing good x. Therefore, from (12), an increase in the production cost via a higher capital rental rate and/or a larger pollution tax will negatively affect the production of good x. It is noted that market competition by the number of firms n can also affect firm's production of good x.

[5] See Corden and Findlay (1975) and Neary (1981). Also see Beladi and Marjit (1996) for a related application of the Harris-Todaro model.

In addition, totally differentiating the factor markets of unskilled labor and capital in (5) and (6)yields:[6]

$$(1+\mu)\,\lambda^{m}_{LX}\,\hat{x} + \lambda_{LY}\hat{Y} = -(1+\mu)\,\lambda^{m}_{LX}\,\hat{n} - [(1+\mu)\,s^{m}_{LX} + s_{LY}]\hat{r} + [(1+\mu)\,\lambda^{m}_{LX} + s_{LY}]\,\hat{w}_R\,, \qquad (13)$$

$$\lambda^{m}_{KX}\,\hat{x} + \lambda_{KY}\hat{Y} = -\,\lambda_{KX}\hat{n} + (s_{KX} + s_{KY})\hat{r} - s_{KY}\,\hat{w}_R - (\,s^{f}_{KX}/\theta_{SA})\hat{t}, \qquad (14)$$

where λ^{m}_{jX} and λ_{jY} are respectively the allocative shares of variable factor j in sectors X and$Y$. Productions of goods X and Y will be further adjusted through the changes in wage rates and capital rentals as indicated in (13) and (14).It is shown in Appendix that for stability, the urban manufacturing sector is required to be capital intensive relative to the agricultural sector in variable production inputs, i.e., $|\lambda^{m}| = \lambda^{m}_{KX}\,\lambda_{LY} - (1+\mu)\,\lambda^{m}_{LX}\,\lambda_{KY} > 0$.[7] Note that from the last term on the right-hand side of (14), a rise in the pollution tax rate works in a similar fashion asa decrease in the supply of capital in the economy. According to the Rybczynski effect, the output of good x will be reduced and the production of good Y will be increased. The changes in outputs will be further adjusted when the changes in the factor returns and number of urban firms are taken into consideration.

As for urban firms, the change in the rental rate for capital can also result in a factor substitution effect between capital and skilled labor, which could affect the composition of the fixed inputs as well as the abatements of emissions. From (7), we have:

$$\lambda_{SA}\hat{a} = (s_{SX} + s_{SA})\,\hat{w}_S - s_{SX}\hat{r} - \hat{n}, \qquad (15)$$

Where s_{SX} and s_{SA} express respectively the factor substitution effects between capital and skilled labor in constituting the fixed inputs in sector X and abating pollution emissions.[8] The pollution abatements would be increased if more skilled labor (induced by the higher skilled wage rate) is employed in the abatement activity. However, the abatements could be lowered either by higher capital rentals or more urban firms because more skilled labor would be employed in the urban manufacturing sector.

3.1. Short-run effects

According to (11), a rise in the pollution tax yields a direct impact on the wage rate of skilled labor via more skilled-labor demand to carry out the activity of abatements. This leads to a factor substitution towards capital by urban firms in the composition of fixed inputs, thereby raising the rental rate for capital. On the other hand, the rise in the pollution tax reduces the production of good x. The output reduction effect caused by the rise in the pollution tax can be solved from (8) – (14) as:

$$\hat{x}/\hat{t} = -\,\varepsilon\{\tau[\lambda_{LY}s_{KY} + \lambda_{KY}s_{LY} + \lambda_{LY}\theta_{LY}s_{KY} + (1+\mu)\lambda_{KY}(\theta_{LY}s^{m}_{LX} + \theta_{KY}\lambda^{m}_{LX}\,] + b s^{f}_{KX}\lambda_{LY}\theta_{LY}\theta^{m}_{KX}/\theta_{SA}\}/D < 0. \qquad (16)$$

where $D = (1 + 1/n)[B + \lambda_{LY}\theta_{LY}\,s^{m}_{KX} + (1+\mu)\lambda_{KY}(\theta_{LY}\,s^{m}_{LX} + \theta_{KY}\lambda^{m}_{LX}\,)] + \varepsilon b\,\theta_{LY}\,\theta^{m}_{KX}\,|\lambda^{m}| > 0$ and $B = \lambda_{KY}s_{LY} + \lambda_{LY}s_{KY}$. The fall in the production of good x will release capital from urban firms to the rural sector. This is referred to as the capital releasing effect.

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[6] The unit fixed cost of urban firm is$f(w_S, r_U)$, and the elasticity of factor substitution between skilled labor and capital is defined as: $\sigma^{F}_{X} = ff_{wr}/f_w f_r$. Following Jones (1965), the factor substitution effect in demand for skilled labor is: $s^{f}_{SX} = \sigma^{f}_{X}\,\theta^{f}_{KX}\,\lambda^{f}_{SX}$, where θ^{F}_{KX} (= rf_r/f) is the cost share of capital in the fixed cost of sector X. Similarly, for the agricultural sector, we define:$s_{LY} = \sigma_Y\theta_{KY}\lambda_{LY}$, where $\sigma_Y = gg_{wr}/g_w g_r$.

[7] This factor intensity condition of the Harris-Todaro model was stated by Khan (1980) and used by Chao and Yu (1992).

[8] We define$s_{SA} = \sigma_A\theta_{KA}\lambda_{SA}$, where $\sigma_A = \alpha\alpha_{wr}/\alpha_w\alpha_r$.

By taking into account the capital substituting and capital releasing effects, from (8) – (14),we can solve for the overall effect of a rise in the pollution tax on the rental rate of capital:

$$\hat{r}/\hat{t} = \theta_{LY}[(1 + 1/n)\lambda_{LY}s^{f}_{KX}/\theta_{SA} - \varepsilon\tau|\lambda^{m}|]/D \gtreqless 0. \tag{17}$$

Note that s^{f}_{KX} expresses the capital substituting effect and $|\lambda^{m}|$ captures the capital releasing effect (via the reduction of output x). In Figure 1, the capital substituting effect induced by the rise in the capital tax makes the VMPL (value of marginal product of labor) curve of sector X(also the corresponding H-T migration curve) to shift leftwards, while the capital releasing effect shifts the VMPL curve of sector Y to the left. Hence, $\hat{r}/\hat{t} > (<) 0$ when the capital substituting effect is stronger (weaker) than the capital releasing effect. This accordingly yields: $\hat{w}_R/\hat{t} = -(\theta_{KY}/\theta_{LY})(\hat{r}/\hat{t}) < (>) 0$.

In Figure 2, we illustrate the case for an economy with a larger capital substituting effect, in which the leftward shift of the VMPL curve for sector X exceeds that for sector Y. Consequently, skilled wage rises but unskilled wage falls. Thus, the wage gap between skilled and unskilled labor is widened. On the contrary, the rental rate for capital may fall when the capital substituting effect is smaller than the capital releasing effect. This case is depicted in Figure 3, in which a smaller leftward shift of the sector X's VMPL curve occurs, compared to the shift of the VMPL curve for sector Y. Unskilled wage can be increased and the wage gap between skilled and unskilled labor could be narrowed.

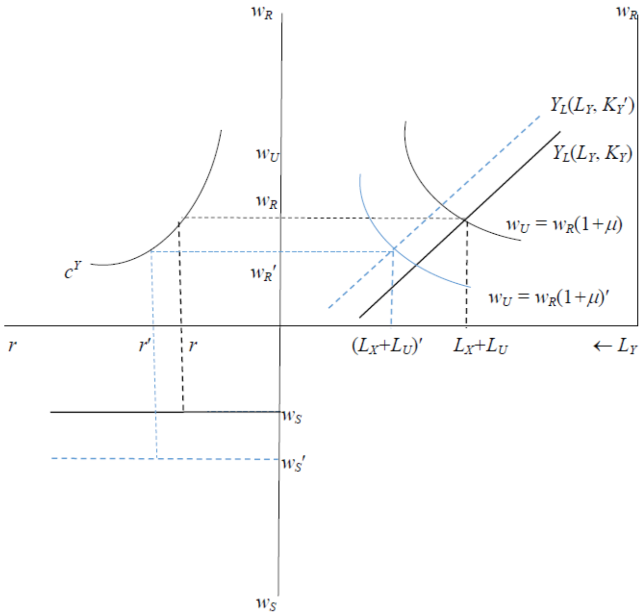

Figure 2. A rise in pollution tax: Strong capital substituting effect

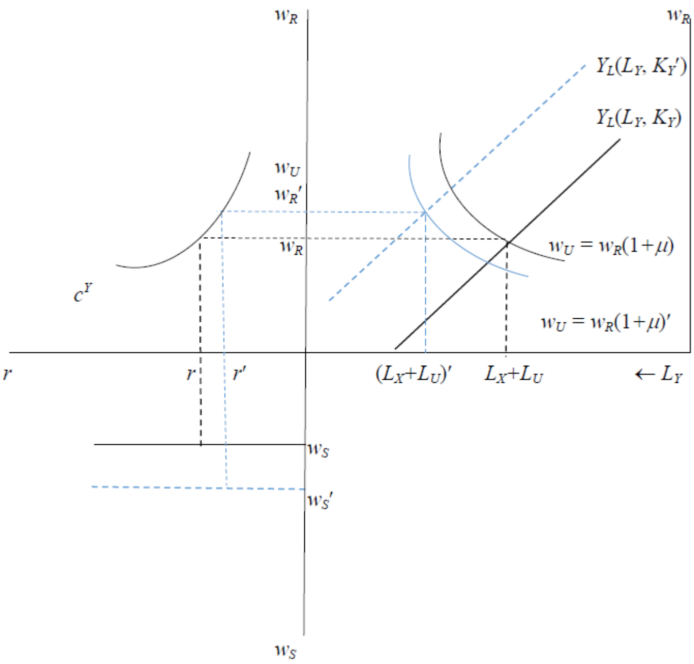

Figure 3. A rise in pollution tax: Weak capital substituting effect

In addition, changes in the rural unskilled wage rates could influence the incentive of unskilled labor for rural-urban migration and hence affect the urban unemployment ratio. From (9), we have:

$$\hat{\mu}/\hat{t} = -[(1+\mu)/\mu](\hat{w}_R/\hat{t}) \gtrless 0. \tag{18}$$

A rise in the pollution tax can reduce (increase) the rural wage rate, thereby leading to more (less) labor migration from the rural to the urban sector.

Note that production of urban good x responds negatively to the rise in the pollution tax. This can also be reflected in firm's profit:

$$d\pi/dt = -x - [f_w(dw_S/dt) + f_r(dr/dt) + xm_r(dr/dt)] \lesseqgtr 0. \tag{19}$$

Note that $d\pi/dt < 0$ in (19) if the capital substituting effect is larger in the short run (i.e., $dr/dt > 0$).

Using the results on production and unemployment in the urban sector, we can evaluate the short-run welfare impact of the pollution tax in the dual developing economy. Social welfare is represented by the indirect utility function adjusted by the environmental damage (ED), $W = V(p, I) - ED$, where $ED = \gamma(X - A)$. Note that γ expresses the direct negative externality of pollution on consumers in the economy. In addition, national income, I, comes from factor incomes and the profits of the urban firms: $I = w_U L_X + w_R L_Y + w_S S + rK + n\pi + tn(x - a)$, where the tax revenue from pollution emissions is returned to consumers in a lump-sum fashion. Totally differentiating the welfare function and then using (1) – (7), we obtain the change in social welfare for the economy:

$$dW = -w_R L_X d\mu + n(p - m - t)dx + n(t - \gamma)(dx - da), \tag{20}$$

where $p - m - t = -xp_x > 0$ with $p_x = -1$. This welfare expression captures four distortions in the economy: urban unemployment, market imperfection, pollution tax and environmental damage. Given the urban minimum wage rate w_u, the second-best optimal pollution tax is:

$$t^o = \gamma + w_R L_X(d\mu/dt)/n(dx/dt - da/dt) + xp_x(dx/dt)/n(dx/dt - da/dt), \tag{21}$$

where $d\mu/dt \gtrless 0$ and $dx/dt < 0$. That is, for the developing economy, the pollution tax can be used to correct the negative externality from environmental damage to consumers, adjusted by urban unemployment and market imperfection. Hence, we have $t^o \lesseqgtr \gamma$, where γ signifies the direct damage of pollution to consumers and is known as the Pigovian tax rate on pollution emissions. When the capital substituting effect is large in urban firms, the optimal pollution tax rate could be lowered because $t^o<\gamma$ with $dr/dt>0$ and $d\mu/dt>0$ in (21), and vice visa.

In general, for a given fixed number of urban firms in the short run, the rise in the pollution tax has an ambiguous effect on the wage gap between skilled and unskilled workers in the economy, depending on the capital substituting and capital releasing effects of urban firms. We summarize the short-run results of the pollution tax on factor returns in the following:

Proposition 1. For a dual developing economy with urban unemployment and market imperfection in the urban manufacturing sector, the rise in the pollution tax raises the wage rate for skilled labor but can lower the wage rate for unskilled labor, when the capital substituting effect on fixed inputs of urban firms is larger compared to its capital releasing effect. Nonetheless, the rise in the pollution tax can raise the wage rates for both skilled and unskilled labor, when the capital releasing effect of urban firms is large.

This leaves the analysis of the short-run impacts of environmental regulations on wage inequality to an empirical question, which will be addressed in section 4.

3.2. Firm dynamics

In the previous section, we have considered the short-run situation in which the number of firms in the urban sector is exogenously given and shown that the rise in the pollution tax can lower profits of urban firms in (21) when the capital substituting effect is strong. This can cause urban manufacturing firms to exit, thereby releasing capital from the urban to the rural sector and hence lowering the rental rate for capital in the economy. Solving (1) – (7), we obtain:

$$\hat{r}/\hat{n} = (1 + 1/n)\theta_{LY}|\lambda|/D > 0, \tag{22}$$

where $|\lambda| = \lambda_{KX}\lambda_{LY} - (1+\mu)\lambda_{LX}^{m}\lambda_{KY} > 0$, expressing the conventional definition for factor intensity in average sense.[9] That is, the urban manufacturing sector X is more capital intensive relative to the agricultural sector Y when total use of capital in sector X, including capital as fixed and variable inputs, is considered. Note that we have $|\lambda|>|\lambda^m|$by recalling that $|\lambda^m| = \lambda_{KX}^{m}\lambda_{LY} - (1+\mu)\lambda_{LX}^{m}\lambda_{KY}$.

On the other hand, the fall in the capital rental rate in (24) lowers the production cost of good Y and hence increases its output. This raises demand for unskilled labor since sector Y is labor intensive, thereby raising the unskilled wage rate in the rural sector:

$$\hat{w}_R/\hat{n} = -(\theta_{KY}/\theta_{LY})(\hat{r}/\hat{n}) < 0. \tag{23}$$

Consequently, the urban unemployment ratio falls:

$$\hat{\mu}/\hat{n} = -[(1+\mu)/\mu](\hat{w}_R/\hat{n}) > 0. \tag{24}$$

In addition, exit of urban firms raises the output and profit of the survival firms:

$$\hat{x}/\hat{n} = -[B + \lambda_{LY}\theta_{LY}s_{KX} + (1+\mu)\lambda_{KY}(\theta_{LY}s_{LX}^{m} + \theta_{KY}\lambda_{LX}^{m}) + \varepsilon b\theta_{LY}\theta_{KX}^{m}(|\lambda|]/D < 0, \tag{25}$$

$$d\pi/dn = -[f_w(dw_S/dn) + f_r(dr/dn) + xm_r(dr/dn)] < 0, \tag{26}$$

where noting that $dw_S/dn = 0$.However, the change in industrial output X of the manufacturing good, $dX/dn = x + n(dx/dn)$, is ambiguous.

The effect of firm exit on factor returns can be illustrated in Figure 4, in which the leftward shift of the VMPL curve for sector Y is larger in reflecting the capital releasing effect from the exit of urban firms. Under this case, the rural wage rate for

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[9] See Chao and Yu (1997).

unskilled labor could increase while the wage rate for skilled labor remains unchanged. This is referred as the firm-exit effect in the urban manufacturing sector.

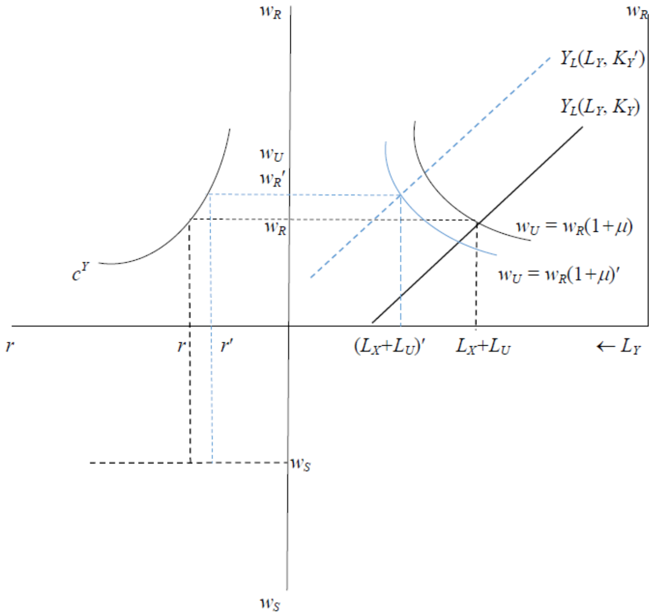

Figure 4. A decrease in the number of urban firms

As for the welfare effect of exit of firms from the urban sector, we can differentiate the welfare function, $W = V(p,I)-\gamma(X- A)$, to obtain:

$$dW/dn= \pi_S - w_R L_X(d\mu/dn) + n(p - m - t)(dx/dn) + n(t - \gamma)(dx/dn - da/dn), \qquad (27)$$

where $d\mu/dn > 0$ by (24) and $dx/dn < 0$ by (25), while $\pi_S[= p(X)x - f(w_S, r) - m(w_U, r)x - \gamma(x - a)]$ denotes the social profit of urban firm. Setting $dW/dn = 0$ in (27) and evaluating it at the Pigouvian pollution tax, $t = \gamma$, the socially optimal number of manufacturing firms in the urban sector is determined at a positive level of social profit:

$$\pi_S^o = w_R L_X(d\mu/dn) - n(p - m - \gamma)(dx/dn) > 0. \qquad (28)$$

This implies that due to urban unemployment and market imperfection, free entry to zero profits would result in too many firms relative to the socially optimal number of firms in the urban sector.[10]

In summary, we have the following proposition for firm dynamics to the urban sector:

Proposition 2. In a dual developing H-T economy, due to urban unemployment and market imperfection, free entry to zero profits leads to excessive number of firms in the urban sector. Hence, exit of urban firms can improve social welfare, in addition to narrow the wage gap between urban skilled and rural unskilled labor in the economy.

3.3. Long-run effects

In the long run, firms can freely enter into or exit from the urban sector. To obtain the total effect of the increase in the pollution tax rate on firm dynamics, we totally differentiate (8) to have:

$$\hat{n} = -(1 - 1/n)\hat{x} - \varepsilon[(1 - b)\,\theta_{KX}^f + b\,\theta_{KX}^m]\hat{r} - \varepsilon[\tau + (1 - b)\,\theta_{SX}^f/\theta_{SA}]\hat{t}. \qquad (29)$$

[10] See Mankiw and Winston (1985) for socially optimal number of firms.

Equation (32) states that number of urban firms depends on firm output, capital cost and pollution tax. By solving (9) – (14) and (29), we can obtain the effect of the rise in the pollution tax on the number of urban firms:

$$\hat{n}/\hat{t} = \{\varepsilon^2(1-b)|\lambda^m|[b\theta^f_{SX}\theta^m_{KX}/\theta_{SA} - \tau\theta_{LY}\theta^f_{KX}] + \varepsilon C[(2\tau/n) + (1-b)(1+1/n)\theta^f_{SX}/\theta_{SA}]$$
$$+ (s^f_{KX}/\theta_{SA})[(1-b)(1+1/n)\theta^f_{KX} + (2/n)b\lambda_{LY}\theta_{LY}\theta^m_{KX}]\}/\Delta, \qquad (30)$$

Where $C = [\lambda_{LY}(s_{KY} + \theta_{LY}s_{KX}) + \lambda_{KY}[s_{LY} + (1+\mu)(\theta_{KY}\lambda^m_{LX} + \theta_{LY}s^m_{LX})] > 0$ and $\Delta < 0$ by the stability condition.[11] Note that $\hat{n}/\hat{t} < 0$ in (30) if $\tau(= t/p)$is initially not too large.Thus, in the long run with free entry or exit of firms, a rise in the pollution tax can lead to exit of manufacturing firms from the urban sector. This can correct the problem of excessive entry in the urban sector when urban unemployment and market imperfection exist in the economy.

The long-run impact of the rise in the pollution tax on the rental rate for capital can be obtained from (9) – (14) and (29)as:

$$\hat{r}/\hat{t} = -(2/n)\theta_{LY}[\lambda_{LY}s^f_{SX}/\theta_{SA} - \varepsilon\tau|\lambda|]/\Delta + (1-b)(\theta^f_{SX}/\theta_{SA})[(1+1/n)|\lambda| - |\lambda^m|]/\Delta. \qquad (31)$$

Compared this long-run effect in (31) with the short-run impact given in (17), the last term in (31) captures the firm-exit effect of the pollution tax on the rental rate of capital.[12] Note that the larger the cost share of skilled labor in the composition of fixed cost in urban firms (via the cost share θ^f_{SX}) in (31) is, the stronger the firm-exit effect is. Since the higher pollution tax increases the cost of skilled labor, urban firms exit and capital is thus released to the rural sector. When this firm-exit effect is strong, as illustrated in Figure 5 by a large shift of the sector *Y*'s VMPL curve to the left, we have $\hat{r}/\hat{t} < 0$ in (31) and hence $\hat{w}_R/\hat{t} > 0$.That is, through the firm-exit effect by releasing urban capital to the rural sector, the rural wage rate for unskilled labor could rise. Nonetheless, when the firm-exit effect is not strong, less firms would exit from the urban sector by the rise of the pollution tax. In this case, only a small leftward shift of the VMPL for sector *Y* curve can occur. This could result in $\hat{r}/\hat{t} > 0$ in (31) and hence $\hat{w}_R/\hat{t} < 0$, as illustrated in Figure 6.

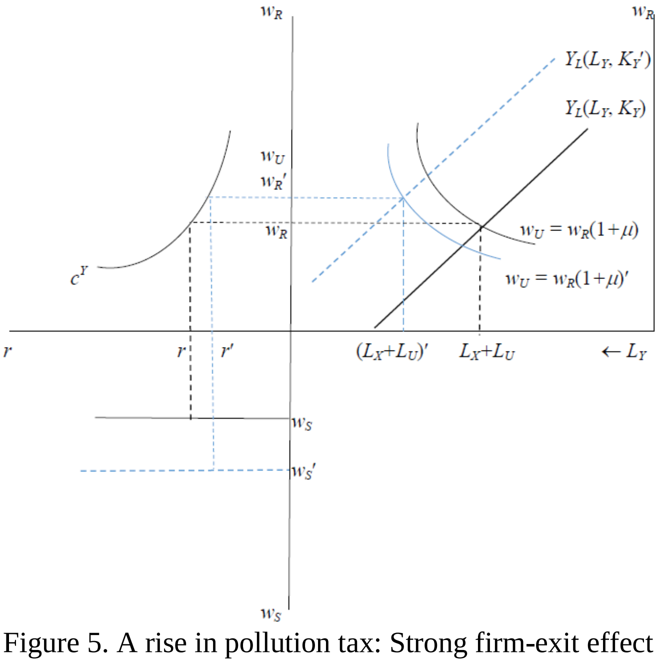

Figure 5. A rise in pollution tax: Strong firm-exit effect

[11] See Appendix.
[12] Clementi and Palazzo (2016) find that firm entry and exit can amplify the effects of aggregate shocks.

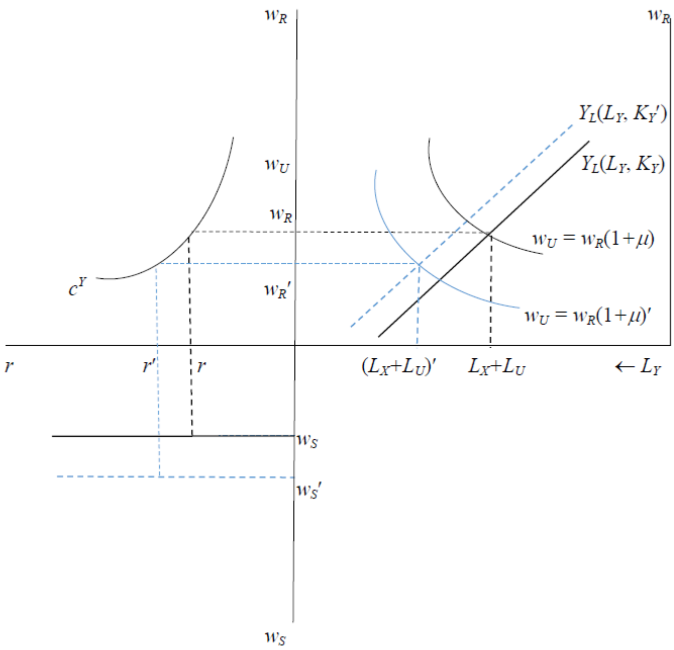

Figure 6. A rise in pollution tax: Weak firm-exit effect

In summary, we have the following long-run results when manufacturing firms exit from the urban sector:

Proposition 3. For a dual developing economy, an increase in the pollution tax can result in exit of firms from the urban sector. In the long run, the rise in the pollution tax can raise the rural wage rate for unskilled labor and thus narrow the wage gap between skilled and unskilled labor in the long run, when the firm-exit effect is strong.

The validity of the above theoretical predictions on the short- and long-run impacts of pollution tax on the skilled-unskilled wage gap of the economy will be investigated through empirical study.

4. Empirical analysis

This section empirically examines both the short- and long- run theoretical predictions obtained in Propositions 1 and 3 in Section 3. The main predictions of our theoretical model are:

1) In the short run with the fixed number of firms, an increase in pollution tax has an ambiguous effect on the skilled-unskilled wage gap in the economy. In other words, an increase in pollution tax can have a positive, negative and no effect on wage gap.
2) In the long run with free entry or exit of urban firms, an increase in pollution tax can cause urban firms to exit. If this firm-exit effect is strong, the rise of pollution tax can narrow the wage gap between skilled and unskilled workers in the economy.

4.1 Empirical specifications

We begin our empirical estimation by testing for the direct, short-run effects of pollution tax on the home country's income inequality. A high pollution tax implies effectively-enforced environmental regulations. Due to data unavailability for pollution tax in most developing countries, instead of testing the effects of pollution tax, in the section we test the relationship between environmental regulations variables (i.e., environmental regulatory enforcement and environmental regulatory stringency) and income inequality. To enable the effect on income inequality to vary according to the level of environmental regulations variable (Naughton, 2014), we include the squared term of environmental regulations variable in the equation. Thus, the baseline model includes both the environmental regulations variable and the squared term of environmental regulations variable.

$$INEQ_{i,t} = \beta_0 + \beta_1 Reg_{i,t} + \beta_2 (Reg_{i,t})^2 + \beta'_3 X_{i,t} + \gamma_i + \varphi_t + \varepsilon_{i,t}, \qquad (32)$$

where the subscripts i and t denotes country and year, respectively. The $INEQ_{i,t}$ is a measure of the income inequality of country i in year t, while $Reg_{i,t}$ and $(Reg_{i,t})^2$represent environmental regulations variable and environmental regulations variable squared. The $\boldsymbol{X}$ is a general set of possible control variables which are often used in the income inequality empirical literature. The γ_i is the vector of dummy variables that account for the time-constant attributes of country i, φ_t is the year dummies and $\varepsilon_{i,t}$is the error term. We estimate the above equation using the robust standard errors to correct for heteroscedasticity. To test the prediction in Proposition 1 for the fixed number of firms in the short run, we examine whether the coefficients β_1 and β_2 are either statistically positive or statistically negative.

Nonetheless, to test Proposition 3 under the firm-exit effect in the long run, we introduce the interaction term for environmental regulations variable to capture the impact of firm exit on environmental regulations variable as follows:

$$\beta_1 = \alpha_1 + \alpha_3 Exit_{i,t}, \qquad (33)$$

$$\beta_2 = \alpha_2 + \alpha_4 Exit_{i,t}, \qquad (34)$$

where$Exit_{i,t}$ is the measure of firm exit. Substituting Equations (33) and (34) into Equation (32), we obtain:

$$INEQ_{i,t} = \beta_0 + \alpha_1 Reg_{i,t} + \alpha_2 (Reg_{i,t})^2 + \alpha_3 Exit_{i,t} * Reg_{i,t}$$
$$+\alpha_4 Exit_{i,t} \times (Reg_{i,t})^2 + \beta'_3 X_{i,t} + \gamma_i + \varphi_t + \varepsilon_{i,t}, \qquad (35)$$

where $Exit_{i,t} * Reg_{i,t}$ and $\alpha_4 Exit_{i,t} * (Reg_{i,t})^2$ are the interaction term for environmental regulations variable and environmental regulations variable squared, respectively. Re-arranging Equation (35), we obtain the following specification:

$$INEQ_{i,t} = \beta_0 + (\alpha_1 + \alpha_3 Exit_{i,t}) * Reg_{i,t} + (\alpha_2 + \alpha_4 Exit_{i,t}) \times (Reg_{i,t})^2$$
$$+\beta'_3 X_{i,t} + \gamma_i + \varphi_t + \varepsilon_{i,t}, \qquad (36)$$

where the combined coefficient of environmental regulations variable $(\alpha_1 + \alpha_3 Exit_{i,t})$ consists of the direct effect α_1 and the indirect effect via firm exit $\alpha_3 Exit_{i,t}$ on income inequality. Likewise, the combined coefficient of environmental regulations variable squared $(\alpha_2 + \alpha_4 Exit_{i,t})$ comprises the direct effect α_2 and the indirect effect via firm exit $\alpha_4 Exit_{i,t}$ on income inequality.

By taking the partial derivative of Equation (36), we obtain the total effect of environmental regulatory enforcement on income inequality. The total effect is given by $[(\alpha_1 + \alpha_3 Exit_{i,t}) + 2 \times (\alpha_2 + \alpha_4 Exit_{i,t}) \times Reg_{i,t}]$. Thus, the main interest for testing the firm-exit effect proposed in Proposition 3 is to determine whether the total effect of environmental regulations on the income inequality is statistically negative or not, and our predict is that an increase in environmental regulations is associated with a reduction in the income inequality in the economy.

4.2 Data and variables

In this section, we describe the data used and proxy for the variables included in the estimation equations in the previous sub-section. For the empirical investigations, we focus on the low- and middle-income countries which are defined according to *World Bank* income level classifications. Our cross-country data set comprises a panel of 37 low- and middle-income countries over the period 2004 - 2006.

4.2.1 Dependent variable

We use Deininger and Squire's (1996) Gini coefficient of income distribution as the measure of a home country's income inequality (*INEQ)*. The Gini coefficient with a value falls between zero and 100 percent is derived from a Lorenz curve, where Gini coefficient of 100 represents perfect income inequality. Thus, the higher the value of Gini coefficient is, the greater the country's income inequality. The data for Gini coefficient is drawn from the World Bank's *World Development Indicators* database.

4.2.2 Independent variables

We employ two measures of environmental regulations, environmental regulatory enforcement consistency and environmental regulatory stringency, reported in the Global Competitiveness Report from 2004 to 2006 editions[13]. These two variables are constructed from the Executive Opinion Survey conducted by the World Economic Forum on representatives of business executives in more than 100 countries around the world. The environmental regulatory enforcement consistency measures the stability, consistency and fairness in enforcing a country' environmental regulations on a scale from zero to seven (World Economic Forum, 2004). For environmental regulatory stringency, the business executives were asked to assess the stringency of his/her country's de facto environmental regulations on a scale from one to seven, where the scale of one indicates that the home country's environmental regulations are lax compared to those of most countries, while seven means that the home country's environmental regulations are among the world's most stringent (World Economic Forum, 2004).

We choose the environmental regulatory enforcement consistency as our primary proxy for environmental regulations because the effectiveness of an environmental regulation requires consistency in environmental monitoring and enforcement. Nonetheless, we consider environmental regulatory stringency as the second measure of environmental regulation to check the robustness of our results. These two environmental regulations variables have been used as the measure of the laxity of environmental regulations in the past environmental economics studies (Kellenberg, 2009; Wagner and Timmins, 2009; Manderson and Kneller, 2012; Chung, 2014). The main advantage of using these two measures is that they measure the strength of the environmental policy across many countries based on the subjective perception of business executives and thus, are related to firms' investment decisions (Kellenberg, 2009; Chung, 2014).

As the proxy of firm exit (*Exit)*, we use the natural logarithm of resolving insolvency distance to frontier score obtained from the World Bank's *Doing Business Survey* for years 2004-2006.[14] The resolving insolvency distance to frontier (DTF) score is a composite business exit indicator, which provides an overall measure of a country's insolvency regulations when closing a business (Strobel, 2010). To determine the DTF, a country's current performance in terms of the efficiency of insolvency regulations is benchmarked against the best performance (or 'frontier') on an indicator across all countries surveyed since 2005. Thus, the DTF measures the distance of a country's insolvency efficiency to the 'frontier'. The closer a country to the frontier is, the higher the DTF score. The resolving insolvency DTF score is calculated by taking the simple average of the DTF scores for the recovery rate and the strength of insolvency framework (Doing Business, 2016). A high resolving

[13] The Global Competitiveness Report started to report the environmental related measure in mid 1990s (Kellenberg, 2009). Unfortunately, the environmental issuesrelated questions were removed from the survey from 2007.

[14] Although the World Bank started reporting the distance to frontier score in Doing Business 2012 report, the data for resolving insolvency distance to frontier score is available from *Doing Business Survey* from 2004.

insolvency DTF score indicates a highly efficient insolvency proceedings with lower exit costs, which implies a lower barrier to exit and a greater ease of closing a business.

Consistent with previous studies on income inequality, we include a number of control variables which have been shown previously to influence income inequality. These control variables are: the growth of per capita real gross domestic product (GDP), inflation, government expenditure, trade openness, human capital, unemployment and the level of financial development. Inflation is the natural logarithm of CPI growth rate and government spending is the natural logarithm of ratio of the government consumption expenditure to the GDP. As a proxy of trade liberalisation, trade openness is calculated by the logarithm of the sum of exports and imports as a percentage of GDP. Human capital is proxied by the natural logarithm of gross primary and secondary enrolment ratio for both sexes. The gross primary and secondary enrolment ratio is calculated by dividing total enrolment in primary and secondary education with the total population (UNESCO Institute for Statistics, 2016). Unemployment is measured by the natural logarithm of the number of unemployed individuals as a share of the total labor force. To measure the level of financial development, we use an indicator often used in financial development literature (Beck et al., 2007, Braun and Raddatz, 2008), that is, the natural logarithm of the ratio of credit provided to the private sector by financial intermediaries to the GDP. The data for the control variables except Human Capitalare drawn from the World Bank's *World Development Indicators* database. The gross primary and secondary enrolment ratio is collected from the UNESCO Institute for Statistics.

4.2.3 Summary statistics

Table 1 presents the summary statistics of the key variables. Table 1 shows that the Gini coefficient for the low- and middle-income countries in our sample ranges from 16.23% (Azerbaijan in 2004) to 64.79% (South Africa in 2006) with a mean of 41.42%. The average environmental regulatory enforcement is 3.25 with a minimum of 2 for Albania in 2005 and 5.2 for Tunisia in 2006. The natural logarithm of exit DTF score is 3.08 with a minimum of -1.47 (Brazil in 2004 and 2005) and maximum of 4.23 (Jamaica in 2004).

Table 1. Summary statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Income inequality (*INEQ*)	123	41.7554	9.9765	16.2300	64.7900
Enforcement	157	3.2535	0.594	2	5.2
Enforcement Squared	157	10.9359	4.0964	4	27.04
Firm exit (*Exit*)	200	3.0756	0.8546	-1.4697	4.2316
Real GDP growth	243	4.5363	4.4165	-11.1666	33.0305
Inflation	223	1.6838	0.9460	-3.2068	3.9408
Government expenditure	229	2.6019	0.4333	1.2414	4.4023
Trade openness	238	4.3630	0.4441	3.2597	5.6716
Human capital	180	4.3925	0.2329	3.3912	4.6633
Unemployment	141	2.1262	0.7337	0.1823	3.8044
Financial development	238	3.0084	0.8601	0.0910	5.0561
Stringency	157	3.3255	0.7180	2.1	5.3
Stringency Squared	157	11.5710	5.2027	4.41	28.09

Note: Income inequality is expressed in percentage. Firm exit, Inflation, Government Expenditure, trade openness, human capital, unemployment, and financial development are calculated as the natural logarithm of the original value.

4.3 Results

Table 2 reports the regressions of environmental regulations variables on income inequality. We estimate Equations (32) and (36) using both fixed and random effects models. The results obtained from the fixed- and random-effects regressions are similar. However, since Hausman test is statistically not significant in these two cases, the random effects estimations are more appropriate. Thus, we will rely on the estimation results using the random effects model for the subsequent discussions.

We first estimate Equation (32) to understand the direct relationship ofenvironmental regulations variable (environmental regulatory enforcement or environmental regulatory stringency) and environmental regulation variable squared (environmental regulatory enforcement squared or environmental regulatory stringency squared) on income inequality. The column 1 of Table 2 shows the results for the baseline model without the interaction terms for environmental regulatory enforcement. Although the sign of Reg and Reg^2 are respectively, positive and negative, they are not statistically significant. This implies that both environmental regulatory enforcement and environmental regulatory enforcement squared have no statistical impacts on income inequality if the interactions with firm exit are omitted. This result confirms the predictions in Proposition 1.

Next, we introduce key interaction terms. From Column 2 we see that the sign of linear term (environmental regulatory enforcement) and squared term (environmental regulatory enforcement squared) are the same as in those in Column 1 and are statistically insignificant. This suggests that both have no impacts on income inequality. This result provides evidence that environmental regulatory enforcement does not have a direct effect on income inequality in linear and quadratic fashions. Again, this result is consistent with the predictions in Proposition 1.

With regards to the interaction terms, the sign of the coefficients for the linear and squared terms for the enforcement level of home environmental regulations are positive and negative, respectively. The positive coefficient on the linear term and negative coefficient on the squared term for the environmental regulatory enforcement suggest the existence of an inverted U-shape relationship between environmental regulatory enforcement and income inequality.

Since the coefficients α_1 and α_{12} are statistically not significant, the total effect is then reduced to $(\alpha_3 Exit_{i,t} + 2 \times \alpha_4 Exit_{i,t} \times Reg_{i,t})$. By focusing on the statistically significant indirect impacts of the environmental regulatory enforcement into account, we can interpret the regression results as follows. Given that the average natural logarithm of firm exit and the average regulatory enforcement level are 3.076 and 3.254 respectively, for a 1 point increase in the level of environmental regulatory enforcement, income inequality decreases on average by 3.96% [i.e., 3.984×3.076 + 2×(-0.81)×3.076×3.254 = -3.96]. In other words, an increase in the environmental regulatory enforcement is associated with a decline in the gap of income inequality if the firm-exit effect is taken into account. This result is consistent with the predictions in Proposition 3.

Moreover, we test the robustness of our main findings using the second measure of environmental regulations (i.e., environmental regulatory stringency) and obtain similar results in Columns (3) and (4). We find that for a 1 point increase in the level of environmental regulatory stringency, income inequality decreases on average by 3.57% [i.e., $3.695\times3.076 + 2\times(-0.73)\times3.076\times3.325 = -3.57$], with the average of environmental regulatory stringency of 3.325.

Table 2. Direct and indirect effects of environmental policy on income inequality: Random effects model

Dependent variable: Income inequality	(1) Enforcement	(2) Enforcement	(3) Stringency	(4) Stringency
Environmental regulations (*Reg*)	7.079	-5.530	4.326	-8.544
	(9.032)	(11.59)	(4.591)	(6.331)
Environmental regulations squared (*Reg*^{2})	-1.250	1.234	-0.588	1.800
	(1.458)	(2.203)	(0.782)	(1.222)
*Reg * Exit*		3.984		3.695
		(1.441)***		(1.569)**
Reg^2*Exit*		-0.810		-0.729
		(0.377)**		(0.350)**
GDP growth	0.0189	0.0789	0.000630	0.0751
	(0.117)	(0.104)	(0.122)	(0.109)
Inflation	-0.392	-0.143	-0.506	-0.228
	(0.364)	(0.306)	(0.390)	(0.315)
Government expenditure	-3.722	-5.378	-3.617	-5.654
	(4.004)	(3.895)	(4.045)	(4.203)
Trade openness	-4.884	-4.369	-5.584	-5.124
	(3.355)	(3.203)	(3.115)*	(3.167)
Human capital	29.48	34.90	28.27	34.66
	(8.602)***	(8.998)***	(9.475)***	(11.31)***
Unemployment	-2.140	-2.288	-2.076	-2.276
	(1.980)	(2.070)	(1.972)	(2.107)
Financial development	4.247	4.075	3.730	3.561
	(2.165)**	(1.800)**	(2.123)*	(1.772)**
Constant	-76.48	-97.75	-64.80	-87.22
	(39.23)*	(40.33)**	(42.37)	(48.16)*
Country dummies	Y	Y	Y	Y
Year dummies	Y	Y	Y	Y
R^2	0.2776	0.6280	0.2980	0.4487
Countries	34	34	34	34
Obs.	62	62	62	62
F- statistics	24.75***	31.78***	25.75***	28.26***
Hausman test	14.76	19.59	14.22	15.66
LM test for random effects	16.96***	16.28***	13.27***	11.79***

Notes: The robust standard errors are reported in parentheses. *, **, and *** indicate statistical significance at 10%, 5%, and 1%, respectively.

5. Conclusions

Using a general-equilibrium framework for a dual developing economy, this paper has investigated the short- and long-run effects of the rise in pollution taxes on income distribution, social welfare and the environment. The developing economy is characterized by an imperfectly competitive urban manufacturing sector, together with a perfectly competitive rural sector. We have paid attention on firm dynamics, in which, due to the favorable development policies, together with lax environmental policy, the number of urban manufacturing firms in the industry tends to be excessive in the developing economies. The production of the urban manufacturing good however generates pollution emissions, which harm consumers. Firms can abate the emissions of pollutants or simply pay pollution taxes. In the short run with a fixed number of urban firms, an increase in pollution taxes may worsen or narrow the wage gap of skilled and unskilled labor, depending on the capital substituting or capital releasing effects of urban firms. Nonetheless, in the long run, the higher pollution tax on urban firms could cause firms to exit from the urban manufacturing sector. Capital is then released to the rural sector and benefits the production of rural workers when the firm-exit effect is strong. This result on income distribution of pollution taxes are empirically confirmed. The higher pollution tax can therefore yield a double dividend in the long run by not only reducing pollution emissions but also narrowing wage gap between skilled and unskilled labor in the developing economy.

Appendix

Letting a dot over a variable represent the time derivative (e.g., $\dot{X} = dX/dt$), the adjustments of the model in (1), (3), (5), (6) and (8) can be linearly approximated as:

$$\begin{pmatrix} \dot{X} \\ \dot{Y} \\ \dot{w}_R \\ \dot{r} \\ \dot{n} \end{pmatrix} = H \begin{pmatrix} \hat{x} \\ \hat{Y} \\ \hat{w}_R \\ \hat{r} \\ \hat{n} \end{pmatrix}$$

where the H matrix is:

$$\begin{bmatrix} -(1+1/n) & 0 & 0 & -\varepsilon b\,\theta^m_{KX} & -1 \\ 0 & 0 & -\theta_{LY} & -\theta_{KY} & 0 \\ (1+\mu)\,\lambda^m_{LX} & \lambda_{LY} & -[s_{LY}+(1+\mu)\,\lambda^m_{LX}] & s_{LY}+(1+\mu)\,s^m_{LX} & (1+\mu)\,\lambda^m_{LX} \\ \lambda^m_{KX} & \lambda_{KY} & s_{KY} & -(s_{KY}+s^m_{KX}) & \lambda_{KX} \\ -(1-1/n) & 0 & 0 & -\varepsilon[(1-b)+b\,\theta^m_{LX}] & -1 \end{bmatrix}$$

The principal minors of the above coefficient matrix are given by

$\Delta_1 = -\,(1 + 1/n) < 0$,

$\Delta_2 = 0$,

$\Delta_3 = -\,\lambda_{LY}\theta_{LY}(1 + 1/n) < 0$,

$\Delta_4 = D = (1 + 1/n)[A + \lambda_{LY}\theta_{LY}\, s^m_{KX} + (1 + \mu)\lambda_{KY}(\theta_{LY}\, s^m_{LX} + \theta_{KY}\, \lambda^m_{LX})] + \varepsilon b\,\theta_{LY}\,\theta^m_{KX}\, |\lambda^m| > 0$,

$\Delta_5 = \Delta$.

The stability condition requires that the odd principal minors are non-positive and the even principal minors are non-negative. Hence, for stability of the model, we need $|\lambda^m| > 0$ and $\Delta < 0$.

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