Who Pay for the Cleaner Air? Distributional Impact of Environmental Policy in a Dualistic Economy

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Abstract

Using a technology where pollution is regarded as by-product of industry's activity and applied in a simple setup of Heckscher-Ohlin-Copeland-Taylor model, this paper analyses the possible distributional impacts of stricter environmental policy in a developing country characterized by the presence of labor-intensive informal sector which may not be a subject to the environmental regulation, and capital intensive formal sector which may face minimum wage policy. The comparative static analysis illustrates that stricter environmental regulation if enforced uniformly accross industries in undistorted labor market, hurts both labor and capital owner, leaving income ditribution unchanged. On the contrary, when economy is dualistic, income distribution may change due to labor reallocation. When the stricter regulation can only be enforced in formal sector, capital owner will be worse-off while labor are better-off. If initially capital reward is higher, the environmental policy will improve income distribution in favor of labor. The change in income distribution is greater when economy is dualistic.

1 Introduction

The huge protest following the government anouncement of gasoline subsidy cut in Indonesia recently, shows one example of how policies may create winners and losers, and if not taken seriously will also create additional costs to the economy such as social unrest or political instability. Not many, especially in Indonesia, however, are aware that gasoline subsidy cut is an example of environmental policies that in many developed countries, in the form of gasoline tax rise, is intended to reduce air pollution. In Indonesia, on the other hand, the motivation of the policy is to reduce the burden on the government budget as it contribute significant share of public spending.

The strong public resistence of the gasoline subsidy cut in Indonesia interestingly had attracted academic debate on whether or not the policy reduce poverty. Some argued that because the share of gasoline consumption is higher for rich people, the policy is progressive or income equalising. If combined with effective compensation of the

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additional fund saved from the subsidy cut, the policy at the end may reduce poverty incidence. At the other side of the debate, however, some argued that the degree of progressiveness may not be high enough and if combined with the ineffectiveness of the compensation schemethe policy may in fact increase the number of the poors[1]. It is worth mentioning, however, that none of this debate talks about the benefit of the subsidy cut in the form of efficiency gain from reduction in the policy distortion. As fuel subsidy creates distorted relative price in the economy, the lower distortion will increase economic efficiency. Revealing to the market the true cost of gasoline also has long run positive impact on the environment from energy substitution. In short, any economic or environmental policy has gain or benefit to be distributed and has loss or cost to be distributed as well. The debate seems to focus only on one side of the story i.e. the cost or who pay for the policy.

It is very natural that environmental policy must have distributional impact. Because the essential purpose of environmental policy is to change consumptions and production patterns. Therefore it is inevitable that there will be winners and losers among households and firms (Kristorm, 2003). Environmental economics literature, however, focus mainly on efficiency as a consequence of treating environmental problems as externality, a departure from pareto optimum[2]. To fill this gap, it is then important that studies on environmental policies analyze how to pursue not only efficient but also fair environmental policies.

Complete picture of the distributional impact of environmental policies has to consider two distinct issues (OECD, 2004). The two inseparable issues are firstly, the concerns related to the distribution of environmental quality and, secondly, those associated to the distribution of financial effects of environmental policies. As discussed previously, the first covers the distribution of benefit i.e. the question on who gain more and who gain less, while the second covers the distribution of costs i.e. who pay more and who pay less. Distribution of environmental quality focus for example on disparities in access to environmental goods, how provision of environmentally related public services such as water access will be distributed, and the heterogeneity in the exposure to environmental bads such as pollution or environmental hazards. Distribution of financial effects, on the other hands refers to the fact that the implementation of environmental policies can be socially regressive, that is, lower-income groups may be subject to a disproportionately higher share of environmental compliance costs. This second aspect actually can be divided into how the environmental policy affect the income side and expenditure side of the households. The topic of this paper is on the income side i.e. how environmental policies may change distribution of income. The more complete studies need also to cover how the environmental policies may effect expenditure pattern, and this is planned to be studied in the research thesis that will be pursued by the author

[1]Source: Selected articles from Kompas daily newspaper.

[2]The highly regarded text on environmental policy from Baumol and Oates (1988) contains mainly the theory of externalities.

using more complete Computable General Equilibrium (CGE) model for Indonesia.

The objective of this paper is to see the possible distributional impacts of stricter environmental policy in a developing country characterized by the presence of informal sector which may not be a subject to the environmental regulation on the one hand, and formal sector which may be a subject to minimum wage policy on the other hand. More generally in the context of the research thesis that the author would like to pursue on the distributional impact of environmental policies in Indonesia, this simple analytical exercise is hoped to give preliminary lessons learned on what need to be accounted for before developing a more complete and bigger CGE model.

Later in this introduction, short review of relevant literature will be briefly discussed, while the rest of the paper will be organized as follow. Section 2 discuss the setup of the model especially the assumption of the technology representation of the industries while section 3 assess in a comparative static analysis the factorial distributional impact of stricter environmental regulation using the model. Section 4 applies the model in a hypothetical numerical example to give clearer illustration how the stricter environmental regulation may affect income distribution. In section 5 lessons learned from this exercise in the context of the author's research proposal will be discussed and concluded.

The comparative static analysis using this very simple model illustrates that stricter environmental regulation if enforced uniformly accross industries in undistorted labor market, hurts both labor and capital owner, leaving income ditribution unchanged. When economy is dualistic, however, the consequently better environmental quality has slightly different distributional effect. Although price of capital and wage in the informal sector fall, labor who manage to still work in the formal sector will be protected from being worse-off. However, some labor could not stay in the formal sector and has to move to informal sector, earning lower wage. In the hypothetical simulation, it is confirmed that contrary to the case where economy is not dualistic, uniform stricter regulation change distribution of income.

When stricter environmental regulation can only be enforced in formal sector, as formal sector is plausibly assumed to be capital intensive, whether or not the economy is dualistic, capital owner will be the only one who will pay for the better environmental quality. However, since, informal sector activity expand, the distributional impact may also depend on the labor reallocation from formal to informal sector. Hypothetical example illustrates that in this case, the change in income distribution, which is in favor of labor, is greater when economy is dualistic.

Overall, this simple exercise using this highly simplified model ilustrate some cases where stricter environmental regulation may not have adverse distributional impact. The simplicity of this model such as the highly restrictive assumption embodied in Heckscher-Ohlin-Samuelson setting, which for example, is strictly long-run, assume closed capital account and disregarding the fact that informal sector commoditiy may not be fully tradable is not intended to give general prediction. It does however leave some lessons learned before we go to a more complete model that need to be developed for further research in the thesis that the author would like to pursue for studying the distributional impact of environmental policies in Indonesia using much bigger CGE model. It stress for example the importance of the information on the size and factor intensity of formal and informal sector, the range of effectiveness of environmental regulation, the abatement technology accross industries, and the initial distribution of income.

The amandement of Heckscher-Ohlin-Samuelson model incorporating minimum wage policy, wage rigidity, or differentiated factor prices is not new. Jones (1971) for example analyzed the impact of distortion in labor market in the form of wage premium in one sector on the income distribution. The others that include explicitly minimum wage for example Johnson (1969) McCulloh (1974), and Neary (1985). A very comprehensive review on factor market distortion, production, and trade was written by Magee (1973). Imam and Whalley (1985) in particular explored the incidence of a sector specific minimum wage in dualistic setting of Hariss-Todaro model. More recently Kar and Marjit (2001) demonstrates the welfare effects of trade policy reforms in a general equilibrium framework, in the presence of an informal sector in the economy. A few however analyze the impact of environmental policy in a dualistic economy.

Some of the few that analyzed the impact of environmental policies in a dualistic labor market are among others Chao et al (2000), Daitoh (2003), and Dean and Gangopadhyay (1997). Chao et al (2000) develops a general equilibrium model to examine the optimal level of environmental preservation in terms of its costs and benefits for a closed and open economy. In an economy consisting of two main activities: farming and processing but use three different input (labor, land, and raw material), Chao et al (2000) atempted to find the optimal environmental preservation and its impact on sectoral unemployment and trade in resources. In the model it is assumed that there is an institutionaly set urban wage that is higher than the market clearing level.

Daitoh (2003) on the other hand, explored sufficient conditions for the welfare-improving environmental policy reform in the Harris–Todaro economy. This paper investigates how a stricter environmental protection policy in the urban manufacturing may affect the manufacturing employment and urban unemployment, and explores the sufficient conditions for welfare improvement. Daitoh (2003) concluded that a rise in the pollution tax rate in the urban manufacturing has spillover effects on the two labor market distortions: the less-than-optimal manufacturing employment and the urban unemployment.

Dean and Gangopadhyay (1997) examined the effects of an export ban on intermediate goods in a three-sector model in which the production of intermediates gives rise to environmental damage. They consider primarily how the (second-best) optimal production and export taxes should be set in the presence of urban unemployment. They consider policy reform as well, making it clear that the export ban aggravates urban unemployment in the short run, but decreases it in the long run.

Compared to the paper described previously, this paper has different emphasis. In the context of the thesis-topic that the author is working on, the focus will be more on the distributional impact of environmental policies, where here, in this paper, for simplication, is represented by the factorial distribution of income. In contrasts to those papers, this paper assume full employment of both capital and labor, that emphasize the long-run nature of the model, and to make consistent with the simple Heckscher-Ohlin model used as a basic starting point. The assumption of full-employment or voluntary unemployment is used by most of the CGE model that mainly reflect the equilibrium of the economy (OECD, 2003). In the context of developing countries, especially Indonesia, where open unemployment is always reported to be very low the full employment may reflect the dualistic nature of the economy. When formal sector can not absorb the excess supply of labor, informal sector may become the runaway place, where labor can get much lower wages and also work with minimum hours.

2 The Model

This model is a simple extension to Heckscher-Ohlin-Samuelson (HOS) 2-goods, 2-factors model, which is standard in international trade literature. Therefore most of the assumption embodied in HOS model will be retained. The economy is assumed to be small in a sense that it can not affect exogenous international price, goods are freely mobile across countries but factors are not. Factor of production, however, can move between industries. Economy is assumed to be always in full employment which emphasize the long-run nature of this model. Throughout the analysis it will be assumed that economy never fully specialized. The extension to this simple HOS model is via the introduction of pollution, as a joint product of firm's activity. Considering the focus will be on developing economies, this model will be applied in a dualistic labor market setting where industries may face different wages, one of which is exogenously determined by government employment policy. However, we will still consider the case of undistorted labor market to make comparison.

2.1 Production and Abatement Technology

Suppose that the economy consist of two sectors or industries, i.e. formal sector (F) and and informal sector (I). Adapting the technological structure used in Copeland and Taylor (2003, 1997), the production structure of the industries are

$$x_i = (1-\theta_i)\, g_i(L_i, K_i) \tag{1}$$

$$z_i = \varphi_i(\theta_i)\, g_i(L_i, K_i) \tag{2}$$

where $i = F, I$. Sector i, jointly produce two output i.e. commodity x_i and emissions z_i.[3] The amount of emission produced depends on the level of abatement activity of the firms. We may interpret g_i as potential output i.e. the amount of x_i to be produced if no abatement activity take place. $g_i(\cdot)$ is increasing, concave, and linearly homogeneous, $0 \leq \theta_i \leq 1$, $\varphi(0) = 1, \varphi(1) = 0$, and $\frac{d\varphi_i}{d\theta_i} < 0$. Industry i endogenously decide how much from every unit of its potential output will be allocated to the production of x_i (or $1 - \theta_i$) and how much will be diverted to abatement activity (θ_i). $\varphi_i(\theta_i)$ captures the transformation between potential output and emission taking into account the abatement activity. For analytical convenience, following Copeland and Taylor (2003), it is assumed that $\varphi_i(\theta_i)$ follow

$$\varphi_i(\theta_i) = (1 - \theta_i)^{1/\gamma_i} \tag{3}$$

where $0 < \gamma_i < 1$ represent the parameter of abatement technology. By imposing this special functional form, in addition to representing emission as output of the production process, pollution can also be treated as input to produce x_i, such that

$$x_i = z_i^{\gamma_i} \left[g_i(K_i, L_i)\right]^{1-\gamma_i} \tag{4}$$

Because equation (4) is Cobb-Douglass, γ_i then may represent the cost share pollution to produce x_i.

2.2 Cost Minimization and Endogenous Emission Intensity

The separability of equation (4) make it possible to break the firm's problem into two stage that is, firstly minimizing the cost of producing potential output $g_i(\cdot)$, and then finding the most efficient way to combine $g(\cdot)$ and pollution (z_i) to produce net output or commodities x_i. In the first stage firm minimize cost given technology of producing potential output. We can write the unit labor and capital demand from this cost minimization as

$$(l_i, k_i) = \arg\min_{L_i, K_i} \{w_i L_i + r K_i : g(L_i, K_i) = 1\} \tag{5}$$

where l_i and k_i are unit labor and capital demand, w_i is price of labor faced by firm i, and r is rental rate or price of capital. It is assumed that w_F is a minimum wage that is higher that would have been in a competitive undistorted labor market set exogenously by government. Wage in informal sector, however, is endogenously determined in the labor market. From this first stage of cost minimization, firms now know how much the minimum unit cost to produce every unit of potential output. This is denoted by $c_i^g = w_i l_i + r k_i$.

[3] Here, there is no distinction between clean and dirty industry as formal and informal sector also produce pollution. Copeland and Taylor (2003) distinguishes between clean and dirty sector, in order to discuss the trade pattern and comparative advantage change after a trade reform.

Having known the unit cost of producing potential output, in the second stage of the optimization, firms minimize cost of producing good x_i (or net output in contrast to potential output) by choosing the optimal level of potential output and amount of emission. The price of emission are the emission tax (τ_i)[4] set by environmental regulator. The unit cost of producing net output, then is

$$c_i^x = \min_{z_i, g_i} \left\{ \tau_i z_i + c_i^g g_i : z_i^{\gamma_i} g_i^{1-\gamma_i} = 1 \right\} \tag{6}$$

First order condition of the optimization problem in equation (6) can be written as $\frac{z_i}{g_i}\frac{1-\gamma_i}{\gamma_i} = \frac{c_i^g}{\tau_i}$. Linear homogeneity of $x_i(\cdot)$ also implies $p_i x_i = c_i^g g_i + \tau_i z_i$. Combining these two equations, we can then solve for emission intensity i.e.

$$e_i = \frac{z_i}{x_i} = \frac{\gamma_i p_i}{\tau_i} \leq 1. \tag{7}$$

As discussed in Copeland and Taylor (2003), it will be assumed that $z_i \leq x_i$ to ensure the optimum emission will be an interior solution. Equation (7) has a very straightforward intuition. Emission intensity, here is endogenously determined and depend on three factors. First, the abatement technology represented by γ_i. If for example, the firm has low abatement technology, then γ_i i.e. the share of emission input cost will be high, and emission intensity will be higher. Secondly, the higher the commodity price, the higher the emission intensity. Commodity price can be interpreted as the opportunity cost of doing abatement activity. If the cost is high, firm will prefer to produce more net output to be sold in market place although they may pollute more and pay tax. Thirdly, the price of emission that has to be paid to the regulator for every pollution emitted by the firm (τ_i).

After we know the emission intensity, total emission in each sector then can be calculated as $z_i = e_i x_i$.It may also be noted that, although the total emission of the industry depend on x_i, which is endogenously determined in the model, emission intensity, however depend only on exogenous factors. Once we know the market price, which will be also equal to international commodity price without distortionary trade policy, given the firm's abatement technology, and unit emission tax, set by the regulator, then we may calculate the amount of pollution produced by the firm for every unit output it produce. Despite its simplicity, this contribution by Copeland and Taylor (2003), however, goes beyond many applied general equilibrium analysis where pollution is only determined by technology disregarding the incentive mechanism that may drive the firm's decision on how much they will pollute.

If we substitute $z_i = e_i x_i$ into equation (4) we can have $e_i^{\gamma_i/(1-\gamma_i)} = (1-\theta_i)$, and if combined with equation (7), we can obtain an expression for θ_i in terms of output

[4]Here, we allow the possibility of policy variable differentiation by regulator to each industry. This will be discussed further in the section on comparative static analysis.

price and environmental policy variable that is

$$\theta_i = 1 - \left(\frac{\gamma_i p_i}{\tau_i}\right)^{\gamma_i/(1-\gamma_i)}. \tag{8}$$

Share of resources allocated for abatement activity than increase as the pollution tax increase, and falls as the price (the opportunity cost of abatement) rise.

2.3 General Equilibrium Factor Price and Allocation

The gross revenue that the firm earn from selling commodity x_i is $p_i x_i$, while its total cost include factor cost and total emission tax paid or $w_i L_i + rK_i + \tau_i z_i$. Competitive free entry condition implies $p_i x_i = w_i L_i + rK_i + \tau_i z_i$. As γ_i is cost share of emission, we know that $\tau_i z_i = \gamma_i p_i x_i$ and can be substituted to have $(1-\gamma_i) p_i x_i = w_i L_i + rK_i$. Recalling that $x_i = (1-\theta_i) g_i$, we can then write the zero profit condition for both firms as written in the first two of the following equation system,

$$\begin{aligned}
w_F l_F + r k_F &= p_F (1-\gamma_F)(1-\theta_F) && (9)\\
w_I l_I + r k_I &= p_I (1-\gamma_I)(1-\theta_I) && (10)\\
l_F g_F + l_I g_I &= L && (11)\\
k_F g_F + k_I g_I &= K. && (12)
\end{aligned}$$

where l_F, k_F, l_I, k_I are unit factor demands as defined in equation (5) and also it should be noted that those factors demand can be written as a function of factor prices. The first two equations says that the unit cost of producing potential output (c_i^g) or the total unit factor payment made by the firm has to be equal to the "effective" price (which we will later denote by q_i) of the potential output received by the firm.[5] The effective or producer's price is less than the commodity price because a portion of θ_i has to be used for abatement activity and γ_i has to be used to pay emission tax. The last two equations are endowment constraint which says that the total allocation of factors between sectors has to be added up to total factor endowment in the economy. The first two equations will determine the factor prices in the economy, and the last two equations will complete the general equilibrium of the supply side i.e. potential output, net output, and emission, of both industries.

3 Comparative Static: Who Pay for the Cleaner Air?

A complete picture of distributional impact of environmental policy has to take into account inseparately two important aspect i.e. how the benefit of environmental policy

[5] Alternative expression of the equations will be in term of unit cost of producing net output i.e. $c_i^x = p_i (1-\gamma_i)$, but $c_i^x = \frac{c_i^g}{1-\theta_i}$. See Copeland and Taylor (2003) for more discussion.

is distributed, and who pay the cost of taking that policy. There are vast amount analysis of the second aspect of the distributional issues but few discuss the former. The fact that to assess the benefit of environmental policy requires calculation of non-marketted commodities such as clean air or aesthetic values are the main reasons. The distributional cost of environmental policy, however, has to consider two different side of story. First, is the financing aspect of that distribution that is how households income will be affected by the policy, and secondly how the policy will change the expenditure pattern across household. This paper is not intended to give complete coverage of the story, but only trying to capture the first.

The setup of the model laid down in the previous section will be used to assess the factorial distributional impact of a stricter environmental policy. Before the policy change it will be assumed that a lower degree of environmental regulation has already taking place, that is at the initial condition we have already $\tau_F = \tau_I = \tau > 0$. The new policy will be in the form of the higher emission tax. For the purpose of comparative static analysis, we will work on the percentage form because it is more handy for algebraic manipulation. The example of analysis using the percentage change of this form can be seen in in Jones (1965) or Kar and Marjit (2001) for more recent paper. We can totally differentiate the equation system (9) to (12) and present it in percentage change as

$$\alpha_{LF}\hat{w}_F + \alpha_{KF}\hat{r} = \hat{q}_F - \left(\alpha_{LF}\hat{l}_F + \alpha_{KF}\hat{k}_F\right) \quad (13)$$

$$\alpha_{LI}\hat{w}_I + \alpha_{KI}\hat{r} = \hat{q}_I - \left(\alpha_{LI}\hat{l}_I + \alpha_{KI}\hat{k}_I\right) \quad (14)$$

$$\lambda_{LF}\hat{g}_F + \lambda_{LI}\hat{g}_I = \hat{L} - \left(\lambda_{LF}\hat{l}_F + \lambda_{LI}\hat{l}_I\right) \quad (15)$$

$$\lambda_{KF}\hat{g}_F + \lambda_{KI}\hat{g}_I = \hat{K} - \left(\lambda_{KF}\hat{k}_F + \lambda_{KI}\hat{k}_I\right) \quad (16)$$

where hat over a variable indicate its percentage change, $\alpha_{Li} = \frac{w_i l_i}{q_i}$ and $\alpha_{Ki} = \frac{rk_i}{q_i}$ are the labor cost share and capital cost share, respectively, in producing potential output while $\lambda_{Li} = \frac{l_i g_i}{L}$ and $\lambda_{Ki} = \frac{k_i g_i}{K}$ are the share of factor employed in each industry. The effective price of potential output is $q_i = p_i(1-\gamma_i)(1-\theta_i)$. Recalling that θ_i is as defined in equation (8). The percentage change in q_i can be written as $\hat{q}_i = -\frac{\gamma_i}{1-\gamma_i}\hat{\tau}_i = -\upsilon_i\hat{\tau}_i$, as we will assume that p_i and γ_i will not change in our comparative static analysis. υ_i can be interpreted as elasticity of producer's price with respect to emission tax. If γ_i is higher representing lower abatement technology or higher cost share of pollution in the cost of x_i production, for every percentage increase in the emission tax rate, given the price of x_i, the more the fall in the unit revenue the firm receive for every potential output they produce.

As $w_i l_i + rk_i$ is the minimum cost of producing one unit of g_i, that is the result of firm choosing input minimizing cost given factor price, there no alternative combination of capital and labor that will yield lower unit cost. Firms vary l_i and k_i to set the derivative of unit costs equal to zero. Alteration in factor proportion must balance out such that the α-weighted average of the change in unit factor demand in each industry is zero. Therefore, it can be shown that $\alpha_{LF}\hat{l}_F + \alpha_{KF}\hat{k}_F = 0$, and $\alpha_{LI}\hat{l}_I + \alpha_{KI}\hat{k}_I = 0$.[6].

The system of equations then, can be written as

$$\alpha_{LF}\hat{w}_F + \alpha_{KF}\hat{r} = -\upsilon_F\hat{\tau}_F \quad (17)$$

$$\alpha_{LI}\hat{w}_I + \alpha_{KI}\hat{r} = -\upsilon_I\hat{\tau}_I \quad (18)$$

$$\lambda_{LF}\hat{g}_F + \lambda_{LI}\hat{g}_I = \delta_F\left(\hat{w}_F - \hat{r}\right) + \delta_I\left(\hat{w}_I - \hat{r}\right) \quad (19)$$

$$\lambda_{KF}\hat{g}_F + \lambda_{KI}\hat{g}_I = -\omega_F\left(\hat{w}_F - \hat{r}\right) - \omega_I\left(\hat{w}_I - \hat{r}\right) \quad (20)$$

where $\delta_F = \lambda_{LF}\alpha_{KF}\sigma_F, \delta_I = \lambda_{LI}\alpha_{KI}\sigma_I, \omega_F = \lambda_{KF}\alpha_{LF}\sigma_F, \omega_I = \lambda_{KI}\alpha_{LI}\sigma_I$,and we assume that there is no change in factor endowment, therefore $\hat{K} = \hat{L} = 0$.

For example, if we want to analyze the effect of stricter environmental regulation in the form of increase in emission tax, then, the first two equations will determine the change in the factor prices. Those solved change in the factor price then could be substituted to the last two equations to find out how the factor are reallocated between industries, as well as the change in output and emission. The following four setting or scenario will be considered. Firstly, the higher emission tax will be effectively forced both in formal and informal sectors (full compliance case). This will be analyzed under assumption of undistorted labor market that is both sectors face the same factor price. In the second scenario, the case where full compliance can not be achieved will be considered. The higher emission tax will effectively be enforced in formal sector only. This situation more resemble the case in developing countries where regulator have limited resource to enforce and assess how much pollution are emitted by informal sectors. The third and fourth scenario will follow the first and the second one but under a setting of dualistic economy.

Before further discussion, the terms full and partial compliance need to be clarified. One of the purpose of the analysis that follows is to see the distributional impact of stricter environmental regulation where in some of the cases, this stricter regulation can only effectively be applied in formal sector. This scenario is merely an attempt to picture the plausible representation of a situation in developing countries where informal sector is spatially scattered, small in firm size, hence difficult to monitor. Because we assume that initially, a lower (or we could say minimum level) of emission tax has already been applied in both sector, a higher emission tax only to formal sector will make the final level of emission tax is differentiated. Some will argue that it just a differentiated tax rate, unrelated to compliance. The term compliance is usually more referred to a situation where a firm decide not to comply to regulation, in this case it may be evading the tax (emission tax evasion) or under-reporting the true emission.

However, it need to be emphasized that the main and most sensible reason that stricter environmental regulation can not be applied in informal sector is related to

[6]See Jones (1965) for detail.

compliance. The question is whether we can represent this compliance problem with lower emission tax rate. It would be argued that we can. From the regulator's perspective, given a certain emission tax in the informal sector, if the emission reported is less than the actual emission, then the tax revenue received is as if the tax rate for the actual emission is lower. This is not sufficient however, as firms also need to see that their "effective" emission tax rate is lower, as we are concerned with the behavior of firms not regulator. The following argument is an attempt to show that in certain cases, firms that do not comply fully to the regulation may be seen as those who see an effective tax rate lower than the formal emission tax rate set by regulator.

Now, suppose that in the informal sector, ν_I is the amount of emission reported (subject to emission tax rate τ_I) which is less than the true emission z_I. It is possible however, that regulator may discover the dishonesty of the firm and a penalty of ϕ may be imposed. Suppose that the penalty is increasing in the amount of under-reporting or $\phi(z_I - v_I)$, where $\phi' > 0, \phi'' > 0$. The probability of being discovered of under-reporting is $\beta(\nu_I)$ which is assumed to be a function reported emission. Regulatory agent may know the expected true emission given, for example, characteristic of the firm, so the greater the amount of emission reported the less probability of being discovered or $\beta' < 0$. In this uncertainty, the firm profit will be either $\pi^1 = p_I x_I(z_I, g_I) - c_I^g g_I - \tau_I \nu_I$, with probability $(1-\beta)$ or $\pi^0 = p_I x_I(z_I, g_I) - c_I^g g_I - \tau_I z_I - \phi(z_I - \nu_I)$, with probability β. The firm maximizes expected profit that will yield the following first order condition

$$
\begin{aligned}
p_I \frac{\partial x_I}{\partial g_I} &= c_I^g && (21)\\
p_I \frac{\partial x_I}{\partial z_I} &= \beta\left(\tau_I + \phi'\right) && (22)\\
\tau_I + \beta'\left(\tau_I\left(z_I - v_I\right) + \phi\right) &= \beta\left(\tau_I + \phi'\right) && (23)
\end{aligned}
$$

Combining the last two equations we can have

$$
p_I \frac{\partial x_I}{\partial z_I} = \tau_I + \beta'\left(\pi^1 - \pi^0\right) < \tau_I. \quad (24)
$$

This equation says that marginal value product of emission has to be equal to the cost or price of the emission or the "effective" emission tax which is less than the tax rate set by regulator. Because the marginal product of emission or $\frac{\partial x_I}{\partial z_I}$ is decreasing with level of emission, the optimal emission under this uncertainty case will be higher than the full compliance. The net effect of the tax rate is as if it is a lower tax but with full compliance. Therefore, In the analysis that follow, it may be argued that the partial compliance scenorio may be represented by $\hat{\tau}_I = 0$ and $\hat{\tau}_F > 0$.

3.1 Case 1: Full Compliance, Undistorted Labor Market

Because, now labor market is undistorted, both sector use the same abatement technology, and are subject to uniform emission tax, the system of equation determining factor prices are given as

$$\alpha_{LF}\hat{w} + \alpha_{KF}\hat{r} = -\upsilon\hat{\tau} \tag{25}$$

$$\alpha_{LI}\hat{w} + \alpha_{KI}\hat{r} = -\upsilon\hat{\tau} \tag{26}$$

It is easy to see that in this special case,

$$\hat{w} = \hat{r} = -\upsilon\hat{\tau} < 0 \tag{27}$$

Because we can interpret pollution as input to production of x_i together with labor and capital, bundled in one single factor i.e. potential output , for every increase in the price of pollution (emission tax), at any given output (commodities) to be produced, firms will try to use less of pollution, and more of potential output. Because marginal productivity of input is declining with the use of that input, marginal productivity of potential output and its price must fall. Price of capital and labor then will fall proportionately. The homogeneity of the x production function and the separability of this production function with potential output g production function make this possible. Labor and capital owner loose, and the owner of the pollution will gain which here is represented by regulator who can set exogenously the price they want to receive for every clean air to be polluted. As we do not discuss the demand side of the pollution, because the concern are more of the distributional cost of environmental regulation, we will not say more of the welfare optimum or endogenous emission tax.

As $\hat{w} = \hat{r}$, w/r does not change, hence there is no change in factor intensity in both sector, and potential output stays the same, no factor reallocation between industries take place. However, as emission intensity across the economy decline as a result of higher emission tax, pollution will decline together with reduction in the production of commodity.

3.2 Case 2: Partial Compliance, Undistorted Labor Market

When higher emission tax can only be effectively enforced in formal sector only, we may represent it with $\hat{\tau}_F = \hat{\tau} > 0$ and $\hat{\tau}_I = 0$. The zero profit condition then become,

$$\alpha_{LF}\hat{w} + \alpha_{KF}\hat{r} = -\upsilon\hat{\tau} \tag{28}$$

$$\alpha_{LI}\hat{w} + \alpha_{KI}\hat{r} = 0. \tag{29}$$

The percentage change in factor prices are,

$$\hat{w} = \frac{1-\alpha_{LI}}{\alpha_{LI}-\alpha_{LF}}\upsilon\hat{\tau} > 0 \tag{30}$$

$$\hat{r} = -\frac{\alpha_{LI}}{\alpha_{LI}-\alpha_{LF}}\upsilon\hat{\tau} < 0 \tag{31}$$

as we assume that informal sector is labor intensive, while formal sector is capital intensive.

In the case where compliance of stricter environmental regulation is only in formal sector, labor owner will be better-off and capital owner will be worse-off. As the policy change work through the change in producer's price i.e. the net revenue per unit of sales of commodity has been reduced because of higher emission tax, the price of input used intensively in formal sector will fall, and price of input used intensively in the non-compliance informal sector will rise. This is, actually, the standard mechanics of Stolper-Samuelson effect that work under Heckscher-Ohlin-Samuelson small open economy setting. Given full-employment assumption, it can be shown that because both sector will use more capital for every labor they used or factor intensity will decline in both sector, formal sector output will contract, and informal sector output will expand. The factor-reallocation that take place, however, does not change the factorial distribution of income, because in this case, it does not matter in which industry factors are employed. However to see precisely, we can use the factor endowment constraint in equation (19) and (20) to find the change in potential output in both sector as

$$\hat{g}_F = \frac{(\lambda_{KF}-1)\,A_1 + (1-\lambda_{LF})\,A_2}{\lambda_{KF}-\lambda_{LF}} < 0 \tag{32}$$

$$\hat{g}_I = \frac{\lambda_{KF}A_1 - \lambda_{LF}A_2}{\lambda_{KF}-\lambda_{LF}} > 0 \tag{33}$$

where $A_1 = \frac{(\delta_F+\delta_I)\upsilon\hat{\tau}}{\alpha_{LI}-\alpha_{LF}} > 0$, $A_2 = -\frac{(\omega_F+\omega_I)\upsilon\hat{\tau}}{\alpha_{LI}-\alpha_{LF}} < 0$, and assuming that because informal sector is labor intensive, $\lambda_{KF}-\lambda_{LF} > 0$. Hence, it is confirmed that activity in formal sector will contract while activity in the informal sector will expand, accompanied by increase in the price of factor that is used intensively in this sector i.e. labor. As $\hat{l}_F = -\alpha_{KF}\sigma_F\,(\hat{w}-\hat{r}) < 0$, then $\hat{L}_F = \hat{l}_F + \hat{g}_F < 0$ and $\hat{L}_I > 0$. There is some labor that moves from formal to to informal sector. In this case, where there is not difference in wages between both sectors, this will not change the distributional story, but it is not the case when labor market is distorted as in the next cases.

3.3 Case 3: Full Compliance, Dualistic Economy

The zero profit condition in the case where the stricter regulation can be enforced effectively in both sectors in a dualistic can be written as,

$$\alpha_{KF}\hat{r} = -\upsilon\hat{\tau} \tag{34}$$

$$\alpha_{LI}\hat{w}_I + \alpha_{KI}\hat{r} = -\upsilon\hat{\tau} \tag{35}$$

To recall, we assumed that w_F is exogenous, and now it does not change, and w_I is determined to clear the labor market in formal sector. The change in the factor prices then can be given as

$$\hat{w}_F = 0 \tag{36}$$

$$\hat{w}_I = \frac{1}{\alpha_{LI}}\frac{\alpha_{LF} - \alpha_{LI}}{1 - \alpha_{LF}}\upsilon\hat{\tau} < 0 \tag{37}$$

$$\hat{r} = -\frac{1}{1 - \alpha_{LF}}\upsilon\hat{\tau} < 0 \tag{38}$$

We can see that while labor in the formal sector does not change because protected by minimum wage policy, wage in informal sector and price of capital fall. Complete distributional impact for dualistic setting, however, has to consider factor reallocation. As in formal sector wage is fixed and rental rate falls, formal sector become more capital intensive. We need to compare the magnitude in the change in the factor price in the informal sector. As $\hat{w}_I \neq \hat{r}$, factor intensity in informal sector change. The percentage change in capital labor ratio is given by $\sigma_I \frac{\alpha_{LF}+(1-\alpha_{LI})}{1-\alpha_{LF}}\upsilon\hat{\tau} > 0$, where σ_I is elasticity of substitution in informal sector. Therefore informal sector also become more capital intensive. When both sector become more capital intensive but informal sector is still more labor intensive, activity in the formal sector will contract and activity in the informal sector will expand. More precisely the change in the activity in both sector can be found using the factor endowment constraints as follow

$$\hat{g}_F = \frac{(\lambda_{KF} - 1)\, B_1 + (1 - \lambda_{LF})\, B_2}{\lambda_{KF} - \lambda_{LF}} < 0 \tag{39}$$

$$\hat{g}_I = \frac{\lambda_{KF} B_1 - \lambda_{LF} B_2}{\lambda_{KF} - \lambda_{LF}} > 0 \tag{40}$$

where $B_1 = \frac{\delta_I \alpha_{LF} + \alpha_{LI}\delta_F}{\alpha_{LI}} \frac{\upsilon\hat{\tau}}{1-\alpha_{LF}} > 0$, and $B_2 = -\frac{\omega_I \alpha_{LF} + \alpha_{LI}\omega_F}{\alpha_{LI}} \frac{\upsilon\hat{\tau}}{1-\alpha_{LF}} < 0$. This result is interesting, because compared to case 1, although stricter environmental regulation is effectively and uniformly enforced in both sector, there is one industry i.e. informal sector which expand their activity, while formal sector contract. Intuitively, it merely reflect the wage rigidity faced by formal sector. As price of capital fall, but wage is given capital requirement in the formal sector will intensify. This also happen in the informal sector, but because wage is flexible there, the capital intensification is not as severe as in the formal sector. Informal sector can absorb the excess supply of labor, while formal sector can't. Activity in the informal sector will expand.

The terms activity, here, is important, because it does not necessarily reflect output in terms of commodity, it only reflect potential commodity and emission to be produced. Activity may increase in one sector but only to reduce pollution. However, as far as distribution are concerned, we can say that there will be a transfer of inputs from formal to informal sector.

From distributional point of view, there will be new groups of labor that initially work in the formal sector transferred to the informal sector and will be worse-off, as they earn lower wages than would have been received in the formal sector. Whether or not the effect of this stricter environmental regulation is progressive (income-equalizing) or regressive remains to be analyzed further and depend on initial distribution of income. This will be discussed in illustrative numerical example in section 4.

3.4 Case 4: Partial Compliance, Dualistic Economy

When compliance is only partial i.e. $\hat{\tau}_F = \tau > 0$, $\hat{\tau}_I = 0$, the change in zero profit condition in the formal and informal sector respectively will be

$$\alpha_{KF}\hat{r} = -\upsilon\hat{\tau} \tag{41}$$
$$\alpha_{LI}\hat{w}_I + \alpha_{KI}\hat{r} = 0. \tag{42}$$

The percentage change in factor prices will be

$$\hat{w}_F = 0 \tag{43}$$
$$\hat{w}_I = \frac{1-\alpha_{LI}}{\alpha_{LI}\left(1-\alpha_{LF}\right)}\upsilon\hat{\tau} > 0 \tag{44}$$
$$\hat{r} = -\frac{1}{1-\alpha_{LF}}\upsilon\hat{\tau} < 0 \tag{45}$$

Although we have the same effect with case 2, where wage rise and rental rate fall, here, the sign in the change of factor rewards, interestingly does not depend on factor intensity, hence even if informal sector is not labor intensive, in a dualistic setting, labor in informal sector will always be better off, and those who managed to stay in formal sector will be protected from income change. Here, eventhough, the factor market is distorted, the Stolper-Samuelson effect still take place, factor that used intensively in informal sector will be better off.

To find out precisely how the factor will be redistributed following this environmental policy shock, we can write the change in potential output in both sector as

$$\hat{g}_F = \frac{\left(\lambda_{KF}-1\right)C_1 + \left(1-\lambda_{LF}\right)C_2}{\lambda_{KF}-\lambda_{LF}} < 0 \tag{46}$$
$$\hat{g}_I = \frac{\lambda_{KF}C_1 - \lambda_{LF}C_2}{\lambda_{KF}-\lambda_{LF}} > 0 \tag{47}$$

where $C_1 = \frac{\delta_1+\alpha_{LI}\delta_F}{\alpha_{LI}}\frac{\upsilon\hat{\tau}}{1-\alpha_{LF}} > 0$, and $C_2 = -\frac{\omega_I+\alpha_{LI}\omega_F}{\alpha_{LI}}\frac{\upsilon\hat{\tau}}{1-\alpha_{LF}} < 0$. As both sectors become more capital intensive than before, hence activity in the formal sector will contract, and activity in the informal sector will expand, there will be labor reallocation from formal sector to informal sector, that may change the distributional story.

4 Hypothetical Illustrative Example

The comparative static analysis discussed previously, conclude that in stricter environmental regulation that can be enforced uniformly across industries in an undistorted labor market will hurt both labor and capital owner, in addition to the lower production of commodities. Similar thing happen when labor market is dualistic, but labor who manage to still work in the formal sector will be protected from being worse-off. In addition to that, however, some labor could not stay in the formal sector, that may have effect on the overall distribution of income.

When stricter environmental regulation can only be enforced in formal sector, whether or not the economy is dualistic, capital owner will be the only one who pay for the cleaner air. This is simply because, formal sector is assumed to be capital intensive. However, since, informal sector activity expand, the distributional impact may also depend the factor reallocation from formal and informal sector. Therefore, whether or not the environmental policy is regressive or progressive depend on the initial income distribution, and also the change not only in the income gap between capital owner and labor, but also between formal and informal labor. To make the story more intuitive in terms of the impact on income distribution, the following discussion will analyze the hypothetical developing economy to see what may happen to the economy especially the income distribution after the stricter environmental policy is implemented.

It is assumed that production function of potential output is Cobb-Douglass such that $g_F = L_F^{\alpha}K_F^{1-\alpha}$, and $g_I = L_I^{1-\alpha}K_I^{\alpha}$, and $\alpha = .25$ that reflect that informal sector is much labor intensive relative to formal sector. This reflects mostly the situation in developing economies. The economy is assumed to be relatively labor abundant such that $L = 30$ and $K = 20$. Parameter of abatement technology is assumed to be the same i.e. $\gamma = 0.01$ and the initial emission tax that is applied in both sector is $\tau_F = \tau_I = 0.01$. The price of commodities produced by formal sector is assumed to higher than those produced by informal sector, which is more plausible in most developing countries. Here price of commodities of formal sector is assumed to be 50% higher. This will make the initial distribution of income is in favor of capital, as wage will be roughly half of the rental rate.

For clearer distributional illustration it may be assumed that the economy consist of 50 households each of which own either labor or capital[7]. This factor endowment

[7] In some cases, it may be more relevant to interpreted labor as unskilled labor and capital as skilled labor or human capital.

is assumed to be continuous. This simplification make possible to construct index of income distribution such as Gini Index which will be equal to zero if the share of income earned by a certain group of households (formal labor, informal labor, or capital owner) is equal to their share in the population.

Four cases that are discussed in the previous section are considered to see the effect of increasing emission tax by from 0.01 to 0.015 (50%).The result of this simulation can be seen from table 1.

<<Insert Table 1>>

As can be seen from table 1, stricter environmental regulation has reduced pollution at the cost of overall output (GDP) and income in all cases. The reduction in pollution is greater when the stricter regulation can be enforced in both sectors. With regard to the distributional cost of this cleaner environment, we can see that in the case where the regulation can be enforced to the whole economy, both factor rewards fall proportionally at the same rate, and it does not change overall distribution of income. Inequality index stay at 0.102. When stricter regulation can only be enforced in formal sector, pollution only fall in the formal sectors, as output of the informal sector expand, even with constant emission intensity, pollution from informal sector still rises, although aggregate pollution drop. As initially, rental rate is higher than wage, and wage rises while rental rate fall, income distribution improve. Gini index drop to 0.098.

Now, we suppose that before stricter environmental regulation take place, government set a minimum wage policy to protect labor in formal sector to be 50% higher than the otherwise competitive wage rate. Although not related to environmental policy, it may be worth discussing the impact of this policy to the initial economy. The minimum wage policy reduce overall output because of the inefficiency in production. As both sectors no longer face the same marginal rate of substitution, economy experience inefficiency in production, and can be represented by equilibrium production down below the production possibility frontier. Capital owner definitely worse-off, as at any given output, higher capital requirement must be accompanied by falling marginal productivity of capital and rental rate. As capital market always in equilibrium and capital account is closed i.e. capital outflow is not possible in this model, minimum wage policy is bad for capital owner.

Wage in informal sector, however, rise slightly. This is quite different with familiar notion in the labor economics literature, where in the partial equilibrium analysis, higher minimum wage in the formal sector will make wage in labor intensive informal sector fall. However, we have to keep in mind that partial equilibrium analysis assumes ceteris paribus, for example, the labor demand curve in informal sector does not shift, as capital and output in the industry stays constant. In this general equilibrium setting, In the informal sector, the drop in rental rate will increase capital demand and labor demand will fall, marginal productivity of labor and wage rise. This result is not new, as it has been confirmed in the trade literature. Johnson (1969) for example stated that in certain case, minimum wage that apply to only part of productive economy may benefit workers in all sectors. Jones (1971) also concluded that minimum wage that is applied in an industry in which labor receive the smaller distributive share (capital intensive sector) must rise the wage rate in both industries. Therefore, it can explain that if the minimum wage policy is intended to improve income distribution, it works. Gini Index has greatly fall from 0.102 to 0.059. However, it is worth stressing that this improving distribution of income is at the cost of economy overall.

In contrast to the case when labor market is undistored, stricter environmental regulation if can be enforced to overall industries now change income distribution although both wage and rental rate fall. Gini index fall from 0.059 to 0.058. This is because there is some labor movement from formal to informal sector and those labor received lower wage than before. Those who pay the most for the better environmental quality is actually those few of labors that can not stay employed in the formal sector following contraction in this industry after the stricter environmental regulation. However, although activity in the informal sector expand, their production of commodity and pollution still fall. In the case when stricter regulation can only be enforced in formal sector, the income distribution improve slightly even more mainly because more of labor are absorbed from formal sector into informal sectors. Now however, informal commodities also rise as well as pollution from informal sector activity.

5 Lessons Learned for Further Research and Concluding Remarks

The result from the simple exercise in this paper may provide some important lessons when we are going to analyze the distributional impact of environmental policy in Indonesia or developing countries in general. As far as the distribution of factor returns as concern, the discussion shows how labor market distortion play crucial role as the distributional impact of environmental regulation are significantly different between the case of dualistic or undistorted labor market. Therefore, study using more realistic model, need to take into account this aspect. We need to know, for example, the information on the degree of the distortion i.e. the gap between minimum wage and competitive wage as well as the effectiveness of the enforcement of this labor regulation. Do all formal sectors comply to this minimum wage policy?

The other important thing the accurate information on the size of the informal sectors in terms of value added, output, and input absorption. This is very crucial in terms of distributional issues. Informal sector may be small in value added compared to formal sector, but it may absorb quite a lot of unskilled labor. This is important not only to confirm that informal sector is really labor intensive, but also to know by how much. This is the information that we need to find for further study because this paper suggest that this is the key that drive the result. In the process, we also may ask whether we can relax how we define informal sector. Can we characterize a subset of industries that will not effectively comply with stricter environmental regulation? Can we confirm that those industries are labor intensive and not subject to minimum wage policy? Size of industry can be a good candidate for making such distinction, but in short, this issue need to be carefully studied.

To step into more general realistic model we may start by relaxing the crucial assumptions and setup used in this simple exercise. Is emission tax relevant instrument in Indonesia, because it necessarily does not exist?. Detail study on the environmental regulation in Indonesia needs to be carried out to be able to find more representative of policy instruments. Even though simulation does not need necessarily represent reality, the likelihood that the policy shock may become possible real policy options will improve the relevance of the study.

From distributional perspective, the simplified assumption of closed capital account i.e. capital can not move abroad if relaxed may drastically change the result. On the other hand, capital mobility among industries in certain situation may also be imperfect. Some portion of capital in every industry may be specific to that industry. This issues need to be carefully considered in the more realistic model.

Commodities produced by certain industry, especially informal sector is very likely to be much less tradable or highly differentiated with the same product with foreign-origin. This may also add more insight into the model. Generalization of Heckscher-Ohlin model, for example in the form of non-tradability and product differentiation may change the well-accepted prediction[8]. In more realistic general equilibrium, together with other factor such as the presence of intermediate goods and more disaggregated industry, definitely need to be accounted for.

The relevance of the demand side of the pollution may need to be discussed if we want to go beyond the question of distributional cost into more general welfare implication. The complete picture of the distributional impact may also call for discussion of the so-called optimum environmental policies. Technically, we can incorporate environmental amenities into utility function and generate for instance the optimum pollution tax. This, however, adds more technical complication because most environmental amenities are non-marketed and raise a question of whether it can be represented in a standard applied general market equilibrium analysis. However, alternatively we may also restrict our analysis in the cost side only, and regards the need for environmental protection as exogenous.

When moving into bigger applied general equilibrium we may need to reconcile the theory and existing database. One example of the basic data issue is the industrial emission. Can we get such representative data from Indonesia? The facts is firms do pollute and emit some quantity of different type of pollutants, but by how much? Most likely

[8] See for example, Falvey et al (1997).

we won't have accurate data on pollution from every industry in disaggregated classification. most CGE models, however, make approximation, for example from the use of energy input where we more probably can access the data. We may also use emission intensity disaggregated by industry from other countries used in other researches.

We also may still be open to widen the type of environmental policy relevant for Indonesia not only restrict on industrial pollution. Jha and Whalley (1999) for example suggest that environmental regime in developing countries is not the same as those of developed countries. Environmental problem related to natural resources such as deforestation, land degradation, and over-fishing may be more prevalent and relevant in developing countries compared to air or water pollution.

Finally, because the focus is on distribution and may be extended to the impact on poverty in particular, methodology to assess the distributional impact from CGE model need to be carefully devised. Most existing CGE model that analyze distributional impact of certain shocks use the concept of representative households i.e. a few household categories and discusses the distribution among those representative households. This method, however is insufficient to picture the reality because it disregards the heterogeneity within each of the representative household and we could not compute accurately standard indicator of poverty or inequality because we have no information of distribution within-household category. Two approaches that may improve the methodology that is planned to be pursued in further research. First is remove the representative households assumptions and instead integrate any number of households available in the survey data into the CGE model, and secondly use a separate microsimulation simulation using household survey to conduct distribution and poverty analysis.

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