

# The Effects of Greenhouse Gases Regulation on Wages and Rents: Policy Issues and General Equilibrium Analysis

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## Abstract

The stringency of environmental policy is likely to change the gains of economic agents. Using a general equilibrium model and an assumption that capital-intensive industries tend to be intensive emitters of greenhouse gases (GHG), we find that a stricter GHG emission scheme will reduce the rent for capital owners but increase the wage for workers. This effect could motivate capital owners or workers to oppose or support a stricter GHG policy. The paper also empirically assesses the model's key assumption by using production input (capital stock and labor), output, and GHG emission data from U.S industrial sectors. The regression result supports a strong positive relationship between the capital-labor ratio and the pollution-output ratio. Therefore, the theoretical analysis is relevant to the actual economy.

## Keywords

Environmental Policy, General Equilibrium Model, Lobby, Incentive, Wage, Rent

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## 1. Introduction

The benefits and costs associated with environmental policy may motivate people with common interest to coalesce for political action to influence the environmental policy making process. Olson (1971)'s classic analysis of economic incentives for collective action suggests that rational, self-interested economic agents have an incentive to form a political action group if net private benefits are expected to be positive [1]. Therefore, when firms in an industry foresee that an environmental policy will increase production cost, they are likely to form an interest group to lobby against that policy. Similarly, individuals who place high value on the environmental quality are motivated to actively participate in political processes that they expect to determine environmental

outcomes. Thus, polluters and environmentalists become the two stereotypical advocacy groups on the environmental issues.

The same winner-loser idea is used in Grossman and Helpman (1994)'s trade policy model and many subsequent studies to explain the behaviors of government, polluters and environmentalists [2]. Lopez and Mitra (2000) present a game-theoretic model in which income transfer from a producer lobby to the government has a negative monotonic relationship to environmental policy stringency [3]. Fredriksson (1997) develops a model in which both environmentalists and producers try to form their own coalition to influence environmental policy [4]. Damania and Fredriksson (2003) show that not only collusive industries with higher collusive profits have a greater incentive to affect policy makers in formulating environmental regulation, but also those industries that are more polluting have equally strong incentive to form and contribute to a lobby so they can influence the environmental policy outcomes [5]. Svendsen *et al.* (2001) in their study on OECD CO<sub>2</sub> taxation found that households pay a tax rate which is six times higher than that paid by the industry because industry lobbies harder against green taxation [6]. Gueterbock (2004) depicted in detail ExxonMobil's scheme to undermine public trust in climate science by providing financial support to their political allies so they can continue to profit substantially from fossil fuel consumption [7].

The literature focuses on the gain and loss of specific types of economic agents faced with environmental regulation but provides only limited explanations for the cost and benefit analysis for agents who do not fit into the stereotypes (environmentalists and polluters). A well-known example is the 1999 coalition between North American labor unions and environmental organizations (Kohn, 2002) [8]. The coalition's goal was to reform the governance of international trade on environmental standards. However, the incentive of labor unions to join forces with environmental groups on a non-labor related issue is intriguing because the direct economic interest cannot provide justification for such a coalition.

After the 1999's coalition, social scientists start to rationalize the engagement of seemingly unrelated interest groups in environmental policy lobbying. Fredriksson and Gaston (1999) find that a union's attitude toward an environmental policy may be determined by the policy's anticipated effect on unemployment [9]. Their study shows that with a risk of unemployment, unions lobby with employers to resist stricter environmental policies. When employment is secure, unions may support policies that reduce employment opportunities for nonunion workers.

Previous studies of the incentives for the nonstereotype groups' involvement in environmental policy process only discuss labor unions' incentives or firms' abilities to lobby for (or against) an environmental policy. The interest of capital owners under a stricter environmental regime has not yet received much attention. In addition, discussion regarding the potential economic impact of a more stringent GHG emission policy on workers has also been limited to the unemployment concerns. Lacking a comprehensive theoretical framework, the cost and benefit of GHG reduction policy for labor and capital owners are discussed separately regardless of the fact that both labor and

capital are fundamental production inputs. To establish a broader structure to explain the effects of a stricter emission policy on capital and labor providers' economic interests, our study aims first to create a framework based on fundamental economic theory and then to empirically assess the underlying assumption of the framework. By investigating impact of GHG reduction policy on the resource owners, the theoretical analysis will provide insight regarding the owners' welfare. The result will help to shed light on their support for or opposition toward a more stringent climate change regime.

## 2. The Model

A stringent climate change regulation achieves its goal through various policy options. These policy options usually require producers to increase labor or capital (or both) to reduce emissions. The technology standard, for example, is a type of regulation that requires firms to use a particular technology to reduce GHG emission. To comply with such a standard the firm has to spend more on capital to procure the specific technology that is required by law. An emission quota is another policy tool which receives much attention in pollution control. Unlike a technology standard, its flexibility allows firms to choose among various compliance options, which creates incentives for producers to increase abatement investment so that the conversion rate between quota and output will be high. Many countries use a Pigouvian tax in emission control. The pollution unit tax can speed up production substitution. Equipment and machinery with lower emission will replace the old ones quickly. Jorgenson and Wilcoxon (1990) find that pollution abatement has emerged as a major claimant on the resources of the U.S. economy as repercussions of environmental regulations [10]. Requate and Unold (2003) investigate use of environmental policy to encourage firms to adopt advanced abatement technology [11]. They find taxes provide stronger incentives than permits, auctioned and free permits offer identical incentives, and standards may give stronger incentives than permits. The increase in abatement provides strong evidence suggesting that once a new environmental instrument is adopted, the production structure and cost for producers will change.

The economy shifts toward a new equilibrium when a stringent GHG emission standard sets new constraints on firms' production functions. Consequently, the input and output proportions may change. Assuming the polluting industry is capital intensive, this study applies Heckscher-Ohlin theory (Leamer, 1984; Ohlin, 1967) to find out how a more stringent GHG policy affects wages and profits [12] [13].

The paper has two parts. In the first part, we build a theoretical model to explain the effects a more stringent GHG emission standard has on factor markets assuming that the high GHG emission industry in US is capital-intensive. The theoretical model will contain a closed economy model and an open economy model. In the second part, we analyze a data set to assess whether the high GHG emission industry in US is actually capital intensive, as assumed in the theoretical model. Although the model is designed to discuss the change in economic advantage of resource owners in US under a stricter GHG emission policy, it has similar implications for other effluent pollution control

and standards as long as similar positive relationship between pollution intensity and capital input intensity holds.

### 2.1. Closed Economy

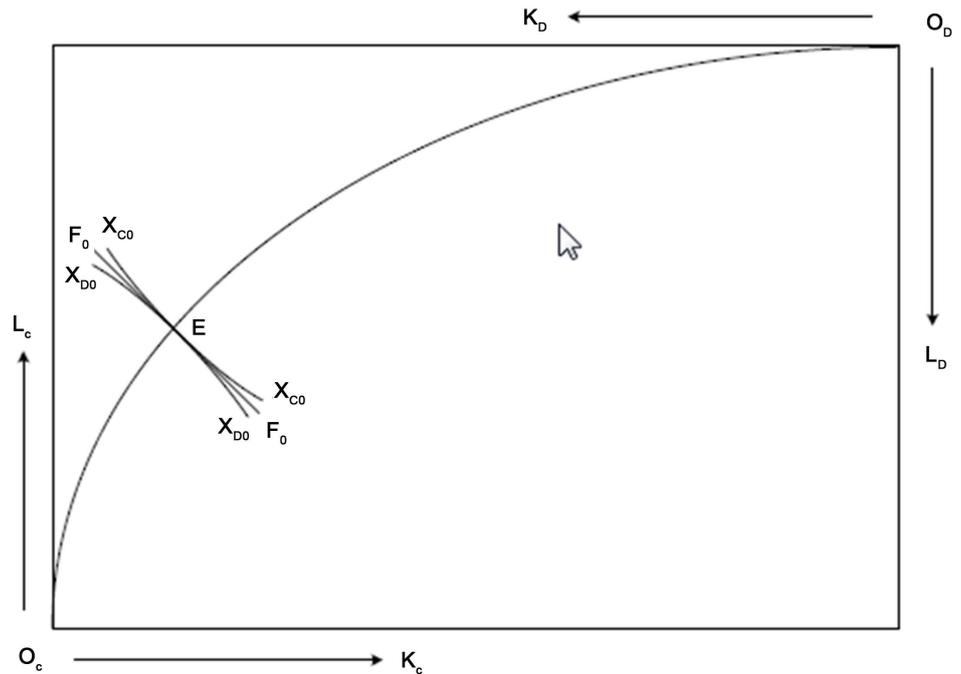
Consider a two-sector, closed economy in which one sector produces high amount of GHG per dollar's worth of output but the other does not. The sectors employ two factors, capital (K) and labor (L), to produce two goods. The industry that has high GHG emission will be called the polluted or dirty industry while the other with low emission will be termed the clean industry. The polluted industry is assumed to be more capital intensive (less labor intensive) than the clean industry. In equilibrium, both factors are fully employed. The two-sector closed economy with full employment is depicted in **Figure 1**.

In **Figure 1**,  $X_{C0}$  and  $X_{D0}$  are the isoquants for the clean and dirty industry.  $\bar{L}$  and  $\bar{K}$  are the economy's endowment of labor and capital.  $E$  is the equilibrium. The absolute value of the slope of line  $F_0 F_0$  is the relative price of capital, that is, the price of capital in terms of labor. We can use the following equations to describe the economy.

$$L_C X_C + L_D X_D = L^D = \bar{L} \tag{1}$$

$$K_C X_C + K_D X_D = K^D = \bar{K} \tag{2}$$

$L_C$  is amount of labor used to produce one unit of output for the clean industry in equilibrium.  $L_D$  is the amount of labor used to produce one unit of output for the dirty industry in equilibrium.  $K_C$  is the amount of capital used to produce one unit of



**Figure 1.** Edgeworth box for a two-sector closed economy.

output for the clean industry in equilibrium.  $K_D$  is the amount of capital used to produce one unit of output for the dirty industry in equilibrium.  $X_C$  is the output of the clean industry in equilibrium.  $X_D$  is the output of the dirty industry in equilibrium.  $L^D$  is the total labor demand.  $K^D$  is the total capital demand.  $\bar{L}$  is the total labor supply.  $\bar{K}$  is the total capital supply.

**Theorem 1:** Assume market always reaches equilibrium, an GHG reduction policy that take the form of a emission tax on the output of the dirty industry in a closed economy will eventually decrease real rent will decrease and increase the real wage. The tax shifts up the supply curve so the market equilibrium price increases and market equilibrium quantity decreases. Therefore, the polluted industry starts to contract<sup>1</sup>. When the polluted industry starts to contract, initially, the wage-rent ratio is unchanged in the factor market. However, the clean industry has to expand in order to reach full employment. But the clean industry is labor intensive. The initial factor price ratio will be inconsistent with the factor market equilibrium, since it will involve an excess demand for labor and/or excess supply for capital. This occurs because at initial factor prices, the expanding industry tries to attract more labor per unit of capital than the contracting industry releases. This leads to a change in relative factor prices.

**Proof:** First we assume one factor input unchanged and allow the other to change with the change in outputs for the two industries. So starting with  $K$  fixed, we have

$$K_C dX_C + K_D dX_D = 0 \quad (3)$$

$$K_C dX_C = -K_D dX_D \quad (4)$$

$$dX_D = -\frac{K_C}{K_D} dX_C \quad (5)$$

Now we allow  $L$  change to with the output.

$$L_C dX_C + L_D dX_D = dL \quad (6)$$

$$L_C dX_C + L_D \left( \frac{-K_C}{K_D} \right) dX_C = dL \quad (7)$$

$$dX_C \frac{L_C K_D - K_C L_D}{K_D} = dL \quad (8)$$

Because polluted industry is capital intensive and clean industry is labor intensive, we have the following relationship :

$$\frac{K_C}{L_C} < \frac{K_D}{L_D} \quad (9)$$

$$K_C L_D < K_D L_C \quad (10)$$

Using the relationship in Equation (10), we find the term  $L_C K_D - K_C L_D$  is positive.

<sup>1</sup>Instead of assuming a tax on the dirty industry, we could assume that the government imposes on the dirty industry a pollution abatement requirement that raises capital and labor input requirements per unit of output proportionately, causing unit costs to rise. Provided that demand elasticity is greater than 1 in absolute value, the industry's revenue will fall. As its revenue falls, its demand for capital and labor inputs will decrease.

So the numerator in Equation (8) is positive. Equation (8) tells that when  $X_C$  increases,  $L$  must move in the same direction.

Next, we assume  $L$  is unchanged and solve for the relationship between  $dX_C$  and  $dK$ . The same process applies and we find,

$$dX_C \frac{K_C L_D - K_D L_C}{L_D} = dK \tag{11}$$

Since the term  $K_C L_D - K_D L_C$  is negative, when  $X_C$  increases,  $K$  must decrease.

Equations (8) and (11) mean that, if both factor markets initially clear, an expansion of the clean industry and contraction of the dirty industry will create, at initial factor prices, excess demand for labor and/or excess supply of capital. When there will be excess demand for labor, the wage must increase. Also, when there is excess supply of capital, the rent must decrease. The adjustment process will happen until the market reaches equilibrium again. This can be proved by the following:

Assume that the production function for the polluted industry, written as

$$X_D = F_D(K_D, L_D) \tag{12}$$

is linear homogeneous, so that

$$X_D = L_D F_D\left(\frac{K_D}{L_D}, 1\right). \tag{13}$$

Defining  $k_D := \frac{K_D}{L_D}$  and  $f_D(k_D) := F_D\left(\frac{K_D}{L_D}, 1\right)$ , we can write,

$$X_D = L_D f_D(k_D) \tag{14}$$

Assuming that  $\frac{\partial F_D}{\partial K_D} > 0$  and  $\frac{\partial^2 F_D}{\partial K_D^2} < 0$ , we have  $f'_D > 0$  and  $f''_D < 0$ . The marginal product of labor ( $MPL$ ) and marginal product of capital ( $MPK$ ) are derived as follows:

$$MPL_D = L_D f'_D(k_D) \left(-\frac{K_D}{L_D^2}\right) + f_D(k_D) = f_D(k_D) - f'_D(k_D) k_D \tag{15}$$

$$MPK_D = L_D f'_D(k_D) \frac{1}{L_D} = f'_D(k_D) \tag{16}$$

Equation (15) and Equation (16) show that the two marginal product only depend on  $k_D$ . Furthermore,

$$\frac{dMPL_D}{dk_D} = -k_D f''(k_D) > 0 \tag{17}$$

and

$$\frac{dMPK_D}{dk_D} = f''_D(k_D) < 0 \tag{18}$$

The real wage rates for labor and capital are determined by the marginal product of labor and the marginal product of capital. That is:

$$MPK_D = f'_D(k_D) = \frac{r}{P_D} \tag{19}$$

$$MPL_D = f_D(k_D) - f'_D(k_D)k_D = \frac{w}{P_D} \tag{20}$$

Analogous equations relate to the clean industry:

$$MPK_C = f'_C(k_C) = \frac{r}{P_C} \tag{21}$$

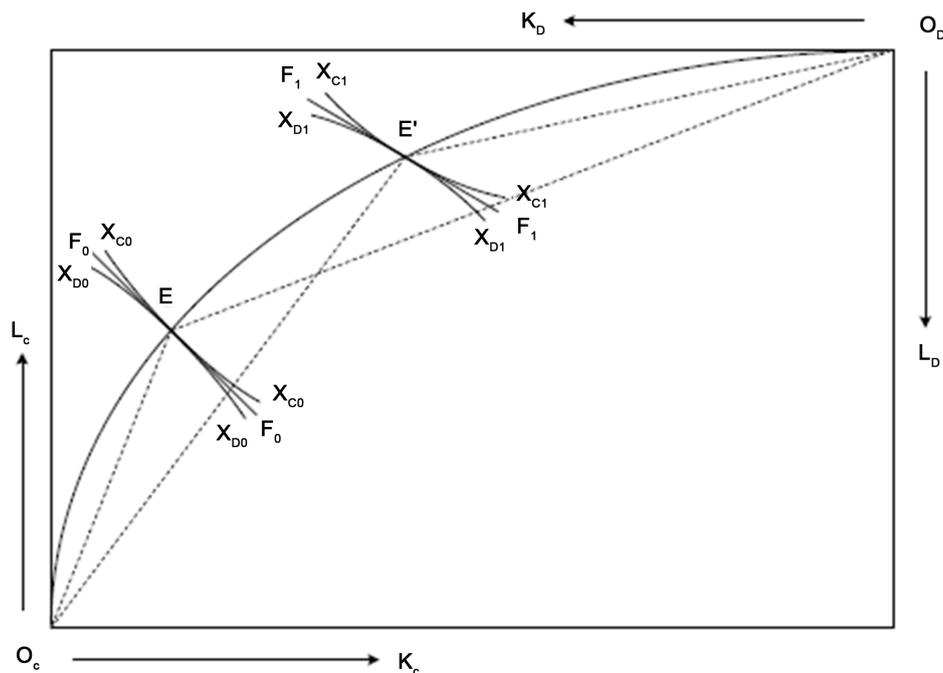
$$MPL_C = f_C(k_C) - f'_C(k_C)k_C = \frac{w}{P_C} \tag{22}$$

$$\frac{dMPL_C}{dk_C} = -k_C f''_C(k_C) > 0 \tag{23}$$

$$\frac{dMPK_C}{dk_C} = f''_C(k_C) < 0 \tag{24}$$

When the new policy shifts the equilibrium from  $E$  to  $E'$  (see **Figure 2**),  $k_D$  and  $k_C$  both rise. Hence,  $MPK_D$  and  $MPK_C$  fall and  $MPL_D$  and  $MPL_C$  rise. Therefore, the real rent will decrease and the real wage will increase.

**Figure 2** illustrates the adjustment process toward the new equilibrium.  $X_{C0}$  and  $X_{D0}$  are the initial isoquants for clean and polluted industries. After the government implements the new regulatory policy on GHG emission, the polluted industry contracts to  $X_{D1}$ . Such contraction leads to excess labor and capital supply. For input factor market to reach full employment, the clean industry will have to expand. Since clean industry is labor intensive, the labor demand from clean industry in expansion

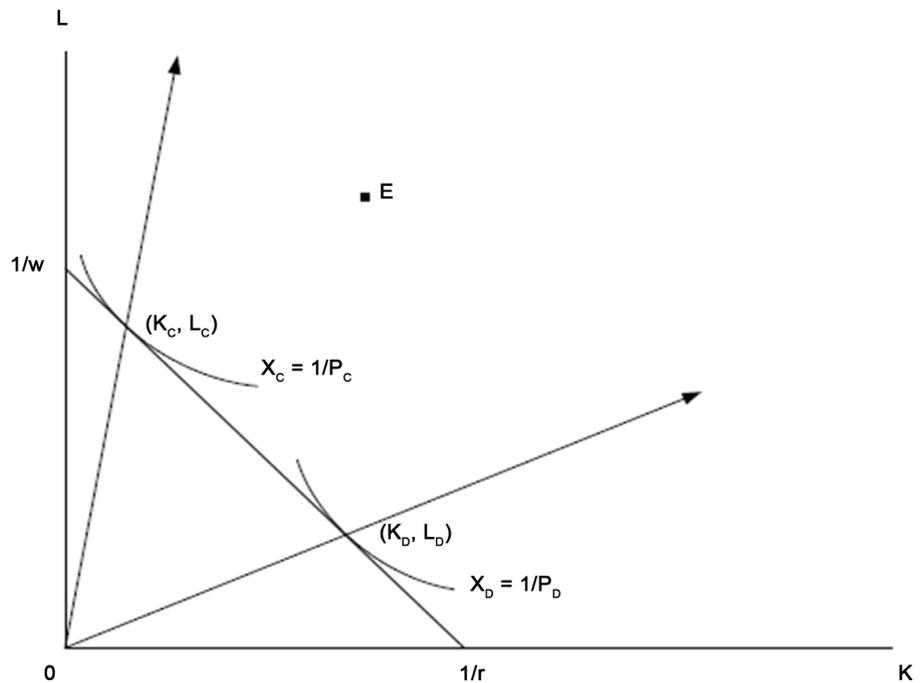


**Figure 2.** Edgeworth box for the new equilibrium.

will be greater than the labor supply released from the polluted industry's contraction while the opposite outcome occurs in capital market. Excess labor demand and excess capital supply would inevitably drive up the wage and lower the rent so the market can be clear again. In **Figure 2**, the new equilibrium emerges at  $E'$  where the demands for labor and capital are equal to supply. The absolute value of the slope of line  $F_1 F_1$  is the new relative price of capital in terms of labor. According to our analysis of factor input prices during adjustment, line  $F_1 F_1$  should be flatter than line  $F_0 F_0$ . It means the new relative price of capital is lower than the initial price at  $E$ .

### 2.2. Open Economy

The open economy model also has two industries, one is dirty and the other is clean. Both industries are assumed to be perfectly competitive. Again, the dirty industry is capital intensive and the clean industry is labor intensive. This model is represented by a Lerner Diagram (**Figure 3**), in which  $X_C$  and  $X_D$  are the unit value isoquants for clean and polluted industries.<sup>2</sup> The two industries' unit value isoquants are tangent to the same unit value isocost line. The absolute value of the slope of the unit value isocost line is the ratio of the rental cost of capital to the wage rate. Assume the endowment of labor and capital,  $E$ , falls inside the cone so that factor markets clear for some combination of positive output levels for the two industries.  $P_C$  and  $P_D$  are the commodity prices for the clean and polluted industry. Because it is an open economy,  $P_C$  and  $P_D$  are exogenous to the model. To avoid a profit or loss that would lead to



**Figure 3.** Lerner Diagram for two sector open economy: prior to a stringent standard is adopted.

<sup>2</sup>A unit value isoquant consists of input bundles that generate the amount of output that has a market value of 1 dollar.

entry or exit, this cost-minimizing bundle of factors must also be worth exactly one dollar, just like the output it produces. Therefore, the isocost line drawn through the tangent point must represent one dollar's worth of factors. Hence its vertical intercept is one dollar worth of labor, or one over the wage  $w$ , while its horizontal intercept is one dollar worth of capital, one over the rental  $r$ , as labeled.

Before a higher GHG standard is implemented, the dirty industry and the clean industry isoquants are tangent with the unit isocost line at  $(L_D, K_D)$  and  $(L_C, K_C)$  respectively. A set of equations describing the relationships among  $K, L, r$  and  $w$  are as follows:

$$L_C w + K_C r = 1 \quad (25)$$

$$L_D w + K_D r = 1 \quad (26)$$

$L_C$  is amount of labor per dollar of output in the clean industry.

$K_C$  is amount of capital per dollar of output in the clean industry.

$L_D$  is amount of labor per dollar of output in the dirty industry.

$K_D$  is amount of capital per dollar of output in the dirty industry.

$w$  and  $r$  are the factor prices.

The two sectors are price takers in the world market. Therefore, prices are treated as given. The isoquants, at their tangencies with the isocost line, have the same slope.

**Theorem 2:** In an open economy, an GHG reduction policy that take the form of a emission tax on the output of the dirty industry also leads to lower real rent will and higher real wage . This is because the new GHG reduction policy requires the polluted industry to use more labor and capital per dollar of output. It shifts out the unit value isoquant for the polluted industry.

**Proof:**

In an open economy, the slope of the old tangent (unit isocost line) is

$$\frac{dL_C}{dK_C} = \frac{dL_D}{dK_D} = -\frac{r}{w} \quad (27)$$

After a stricter GHG standard is implemented, the new tangent is illustrated in **Figure 4**. At cost minimization, the slope of the new tangent is :

$$\frac{dL'_D}{dK'_D} = \frac{dL'_C}{dK'_C} = -\frac{r'}{w'} \quad (28)$$

And

$$\left| \frac{dL}{dK} \right| = \frac{dX}{dK} \frac{dL}{dX} = \frac{MPK}{MPL} \quad (29)$$

Once again, MPK stands from marginal product of capital and MPL stands for marginal product of labor. Equation (29) holds true at equilibrium.

Therefore, in the old equilibrium

$$\frac{MPK_D}{MPL_D} = \frac{MPK_C}{MPL_C} = \frac{r}{w} \quad (30)$$

Similarly, at the new equilibrium,  $\frac{MPK_D}{MPL_D} = \frac{MPK_C}{MPL_C} = \frac{r'}{w'}$ . From the Lerner Diagram,

we can see that the new tangency on the clean industry's isoquant is to the right of the old tangency. Therefore, at the new tangency, the capital labor ratio is greater than the old tangency. It means  $MPK_C$  will become lower and  $MPL_C$  will become greater. Thus the rent-wage ratio ( $r/w$ ) will fall from the old equilibrium to the new equilibrium.

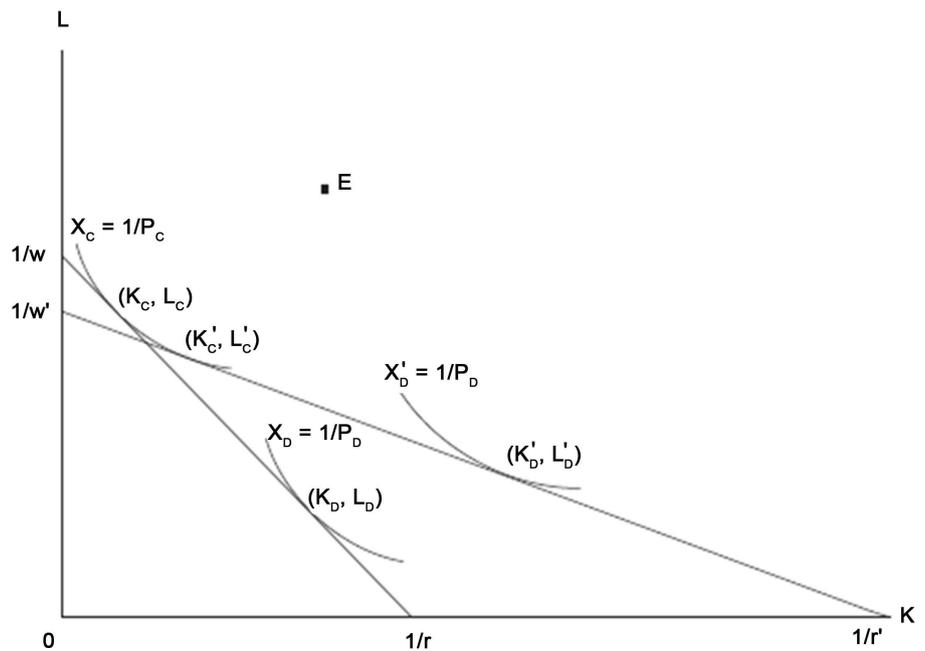
**Figure 4** describes such a change. A new isocost line will be established tangent to the new isoquant of the polluted industry and the old isoquant of the clean industry. At the new tangency, the amounts of labor and capital used are  $L'_D$ ,  $K'_D$ ,  $L'_C$ , and  $K'_C$ .

At cost minimization, the slope of the new isocost line through two tangent points is  $\frac{r'}{w'}$ . From the Lerner Diagram, we can see that  $1/r'$  is greater than  $1/r$  and  $1/w'$  is small than  $1/w$ . In another word,  $r'$  is smaller than  $r$  and  $w'$  is greater than  $w$ . It means the absolute value of the slope of the new isocost line is smaller than that of the old isocost line. Compared with the initial equilibrium, the rent will be reduced and the wage rate will be higher.

The implication for the model (in which the dirty industry is capital intensive) is that capital owners have an incentive to oppose a stringent GHG policy and workers have an incentive to ally themselves with environmental groups lobbying for a stricter standard.

### 3. Empirical Study

The theoretical models developed above are based on the assumption that the polluted



**Figure 4.** Lerner Diagram for two sector open economy: after a stringent standard is adopted.

industry is capital intensive. The assumption captures the general impression that high GHG emission industries in US seem to involve high levels of capital in production. The petrochemical industry and oil drilling industry are examples. However, to strengthen our theoretical work, it is important to use empirical data to verify this assumption. The aim of this section is to find out if there is a positive correlation between capital labor ratio and GHG emission-output ratio across US industries.

The US has extensive time-series production input and output data. We use total hours of labor input and productive capital stock to estimate the labor-capital ratio at the industry level. When estimating capital input as the production factor, the common practice is to include equipment and structures. Inventory and land are not included. Both capital and labor data come from the Bureau of Labor Statistics (BLS). The capital input data includes the following sectors: private business, private nonfarm business, manufacturing, farm sector and nonfarm nonmanufacturing. Productive capital stocks are derived from the National Income and Product Accounts (NIPA) investment which uses the perpetual inventory method and assumes that capital services decline as a function of age to obtain the estimates of capital stock value. BLS provides industry level capital input data and labor input data based on the North American Industry Classification System (NAICS). The NAICS code is the standard used by Federal agencies in classifying business establishments for the purpose of collecting, analyzing, and publishing statistical data related to the U.S. industries.

We calculate industry level pollution intensity as pollution per unit of value added.<sup>3</sup> The data on value added by industries (as delineated in NAICS) are provided by the Bureau of Economic Analysis (BEA).

The US Environmental Protection Agency (EPA) ranks the industrial sectors as the major greenhouse gas contributing end-user sectors. The most detailed source of information on U.S. GHG emissions is the Inventory of U.S. Greenhouse Gas Emissions and Sinks [14], issued by the EPA Office of Atmospheric Programs. This source provides detailed emissions data, broken down by industrial process. Only in a few cases (cement manufacturing, for example) does the breakdown by process correspond to the breakdown by NAICS code sector. We find that it is impossible to derive sector-specific information directly from the process data provided in the Inventory. However, in our study, a sector-specific breakdown is desirable. One way to derive reliable industrial GHG estimates is to convert the current sectoral energy consumption data to carbon dioxide equivalence. This is the approach that is recommended by the National Center for Manufacturing Sciences. According to EPA, energy consumption is the major source of industrial GHG emission. The approach adopted for our study is based on the fact that, for many sectors, the total contribution of the sector processes to overall GHG emissions is dominated by the carbon dioxide generated from fossil fuel combustion. Therefore, data from the Energy Information Administration (EIA) of the

<sup>3</sup>Valued-added output is an appropriate measure for industry output because it excludes the value of intermediate inputs. Some industries have a high value of intermediate inputs, using the value of total commodity output in this case will exaggerate the value of output the industry creates. By choosing value-added as the measure of output we can avoid overestimating the actual value of the output.

US Department of Energy Information on energy consumption for specific fossil fuel types, broken down by sector, can be used to convert to sectoral GHG emission. Because the carbon content of each fossil fuel type is known, using an estimated conversion factor one can convert fuel usage figures into GHG emissions for each sector covered by the EIA energy usage information.

EIA has energy consumption data for 21 manufacturing sectors based on 3 digit NAICS code for years 1998, 2002 and 2006. The 21 manufacturing sectors in the EIA dataset are listed in **Table 1**.

**Table 1** clearly shows that major industrial sectors are included in the EIA energy statistics. The data capture most of the emission in manufacturing industry. Cross referencing the industry sectors in both EIA data and EPA inventory, EIA fossil fuel consumption data based on NAICS codes provide a reasonably close mapping to the selected sectors that are of interest for the GHG concern. For example, sectors such as Agricultural Chemicals, Aluminum, Automobile Assembly, Cement, Chemicals, Computers and Electronics, Iron and Steel, Petroleum Refining, Plastics, Pulp and Paper, Rubber, Semiconductors, Stone, Clay and Glass, Textiles, and Wood products have been the important GHG contributors in the manufacturing industry, according to the inventory (US EPA report). All of these sectors are categorized into the NAICS codes that are listed in **Table 1**. Their corresponding 3 digit NAICS code are: 325, 331, 336, 327, 325, 334, 331, 324, 325, 322, 326, 334, 327, 313, and 321.

Total energy consumption for each sector is estimated based on data for energy generated from the following energy sources: net electricity, residual fuel oil, distillate fuel oil, natural gas, liquefied petroleum gases (LPG) and natural gas liquids (NGL), coal, coke and breeze<sup>4</sup>, other, and shipments of energy sources produced on site. The total energy consumption is the sum of all of the listed energy sources, including

**Table 1.** Industrial sectors that are listed in the EIA energy consumption dataset.

NAICS	Industry	NAICS	Industry
311	Food	326	Plastics and Rubber Products
312	Beverage and Tobacco Products	327	Nonmetallic Mineral Products
313	Textile Mills	331	Primary Metals
314	Textile Product Mills	332	Fabricated Metal Products
315	Apparel	333	Machinery
316	Leather and Allied Products	334	Computer and Electronic Products
321	Wood Products	335	Electrical Equip., Appliances, and Components
322	Paper	336	Transportation Equipment
323	Printing and Related Support	337	Furniture and Related Products
324	Petroleum and Coal Products	339	Miscellaneous
325	Chemicals		

<sup>4</sup>A by-product of coke manufacture; it is the residue from the screening of heat-treated coke. The particle size is less than 10 mm.

“other”, minus the shipments of energy sources produced on site. It is the total amount of first use of energy for all (fuel and nonfuel) purposes. Shipments of energy sources produced on site are those shipments produced or transformed on site from the nonfuel use of other energy sources. For example, at an establishment that processes coal to make coke for later use, the entire quantity of coal is counted as first use. Any onsite consumption of coke is not counted as first use because it would duplicate the coal use. If some of the coke is then sold to another establishment, then that second establishment will consider this coke to be a shipment of an offsite-produced energy source. Hence, the second establishment will count this coke as its first use, thereby resulting in double counting. In order to eliminate the double counting, the energy equivalent of the coke shipment must be subtracted from first use.

The Environmental Roadmapping Initiative of the National Center for Manufacturing Sciences provides conversion factors for each EIA’s fuel type. **Table 2** shows the GHG conversion factors for the EIA energy sources.

Using the conversion factors, we derive the total GHG emission from EIA sectoral energy consumption data. Then dividing GHG emission by value added, we can obtain data on emission per dollar, which is the dependent variable in our model. Using the capital labor ratio as the regressor, we obtain the regression result shown in **Table 3** model 1.

**Table 2.** GHG conversion factors by energy types.

Energy source	Conversion factor (Tg CO <sub>2</sub> eq per trillion Btu)	Notes Teragram (Tg) is a weight measurement which equals 10 <sup>12</sup> grams.
Net electricity	0.075	Energy bought and generated, minus energy sold offsite. Factor is a midrange value, since fuel type used for generation is unspecified.
Residual fuel oil	0.0788	Nos. 1, 2, and 4 fuel oils and Nos. 1, 2, and 4 diesel fuels.
Distillate fuel oil	0.0732	
Natural gas	0.0531	Examples include: ethane, ethylene, propane, propylene, normal butane, butylene, ethane-propane mixtures, propane-butane mixtures, and isobutene.
LPG and NGL	0.0623	
Coal	0.0940	Includes net steam, and feedstocks. Factor is a midrange value.
Coke and Breeze	0.0937	
Other	0.075	Shipments to other sites of material to be used as fuel. This quantity is subtracted from the others, to avoid double counting. Factor is a midrange value.
Shipments of Energy Sources Produced On Site	0.075	

**Table 3.** Regressions for pollution per dollar of output.

	Model 1	Model 2
Constant	-0.84 (-2.56)	-0.14 (-0.311)
K/L ratio	0.026 (11.36)	0.027 (12.519)
Dummy02		-0.55 (-0.961)
Dummy06		-1.81 (-3.113)
$\bar{R}^2$	0.7072	0.7471

The numbers in parentheses are t-ratios. The numbers above those in parentheses are point estimates of coefficients.

The sign of the coefficient for K/L ratio is positive, which is consistent with our expectation. It means that in our panel dataset, high capital intensity is positively associated with high GHG emission intensity. Furthermore, the t ratio for capital is large and significant. It supports our assumption that a polluted industry is indeed capital intensive in US.

Because industry level time series data are used in our data, time-varying factors such as technological progress, weather/temperature, change in regulations, or economic cycle could also affect GHG emission per dollar. Therefore, we need to extend our model by adding year dummy variables to separate influence of the time related factors on pollution intensity to increase the robustness of the model. The regression result for the second model is also in **Table 3**. Model 2 shows the coefficient of K/L ratio is consistent with the result in the first regression model and its value and t ratio are larger than the result in the first model. Model 2 also has better goodness of fit ( $\bar{R}^2$ ).

There are two year dummies in model 2, but only the coefficient for year 2006 reaches the level that is necessary for statistical significance. This seems to be encouraging because it shows that the US major manufacturing sectors have decreased GHG intensity in the production process in the recent years. The reduction could be the result of the change in both environmental regulations and the public awareness in response to the concern of global warming. However, complete time series data and further research are required to pin down the underlying factors that contribute to the improvement.

#### 4. Conclusions

When general equilibrium theory is applied to predict the effect of a higher GHG emission standard on factor prices, the inference is that wages will rise and the rental cost of capital will fall. If workers and capital owners take political positions based on economic self interest, stricter GHG policies will be supported by the former and opposed by the latter. The result of our empirical study shows strong evidence to support the assumption that the capital intensive sectors tend to produce more GHG since the coefficient of capital-labor ratio is positive and statistically significant. It suggests that when US economy becomes more capital abundant, it is likely to be dirtier if there is no adequate government intervention on GHG emission. Policy makers should

be cautious about the environmental consequence when designating investment policy to increase capital stock in the production process to pursue economic development.

An important implication from our result is that capital owners have an incentive to join forces across sectors to oppose the GHG reduction policy. The imposition of a stringent GHG control policy will decrease the capital price relative to product prices and increase wages relative to these product prices. This provides incentives for self-interested capital owners to oppose to a stricter environmental policy and for laborers to support it.

To the extent that firms use their own capital, rather than borrowed capital, firms in capital-intensive industries will have an incentive to join the coalition against GHG reduction policies. For the firms that rely on capital markets to finance their operation, their creditors and shareholders would be pleased to see corporate lobby against higher GHG standards. In most industrial countries, GHG reduction policy has thus far targeted only the electricity companies. With stricter policies towards climate change, the energy end users will soon find themselves under government regulation for GHG especially the major manufacturing sectors that have high electricity demand. As a result, there is a great likelihood that the rent seeking, highly capitalized industry will vigorously work together against the GHG abatement policy.

In view of the political power of capital owners and capital-intensive corporations to block GHG emission reduction regimes that threaten their economic interests, mitigating the negative impact of environmental policy on the return to capital should be an important consideration in strategizing US national climate change policy. This would help the reduction scheme to receive widespread bipartisan support. Any policy options that avoid contraction of the high emission industry would alleviate the rent loss for capital owners. For example, capital owners and capital-intensive corporations would probably accept a government program to subsidize incentive to encourage innovation on GHG emission production technology in order to lower production cost.

Another approach to create a political environment conducive to the passage of stricter GHG emission regulations involves changing the electoral process. By putting a limit on corporate spending in campaigns for Congress, the heavy corporate clout in the capitol would be restricted. Laborers and capital owners would then have a fair chance to have their voices heard in Congress on the climate change policy. However, the recent Supreme Court decision that rejects limit on corporate spending in election campaigns<sup>5</sup> seems to lead US politics to the opposite direction [15].

Skepticism about climate science may seem particularly surprising when voiced by political leaders of the United States, a country at forefront of scientific research. However, applying general equilibrium theory to the U.S. economy, we find that capital owners will face rent decreases while laborers will receive wage gains if stricter GHG standards are adopted. This class divide could be an underlying cause for the polarized policy preferences on climate change issues. The results of the Gallup Environmental Poll, which span a decade, also confirm the gap between climate views expressed by

<sup>5</sup>Available at: <http://www.nytimes.com/2010/01/22/us/politics/22scotus.html> [accessed on July 10, 2011].

Republicans and Democrats. In the 2008 Gallup Poll, we see that Republicans have become somewhat less likely over the past decade to believe that global warming is already occurring (from 48 to 42 percent), while Democrats have become much more likely to hold this belief (from 52 to 76 percent) (Dunlap and McCright, 2008) [16]. Our paper's analytical results provide a possible explanation of the divergent trends between Republicans and Democrats by suggesting that the economic interests of capital and labor may be one of the fundamental factors. Being the world's second largest CO<sub>2</sub> emitter, the US should actively seek feasible reduction choices that would diminish economic impact associated with GHG reduction policy, and this will undoubtedly help the two parties to reach political compromise on the US climate change policy.

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