Converting Implicit into Pure Carbon Taxes*

By

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1. Introduction

Global warming and the greenhouse effect have become one of the most important issues in international society. In OECD countries, (m)any existing taxes have been redesigned to reflect better their environmental purposes, and more goods are taxes for environmental purposes (OECD,1996:9). Northern European countries have restructured the existing energy taxes to introduce carbon taxes that could abate the emissions of CO₂. The existing energy taxes on fossil fuels are not introduced to reduce intentionally the emissions of CO₂. The existing fossil
fuels taxes, however, have unintended beneficial effects on reducing CO₂ emissions in comparison with no fossil fuels taxes, and so often they are referred as implicit carbon taxes.

In Japan, carbon taxes have become popular with policy-makers, but there is little acceptability of introducing a new carbon tax. The Japanese tax system has also customs duty and several excise taxes on petroleum products, or implicit carbon taxes (Figure 1). For example, Customs Duty and Petroleum Tax are imposed on the shore in importing crude oil, petroleum products, LPG, and LNG, and when petroleum products are consumed as energy, excise taxes are imposed on such energies as Gasoline, Gas (Light) Oil, Jet Fuel and LPG. However, Naphtha, Kerosene, and Heavy Oil are free of excise taxes. And coal is also free of excise taxes.

The purpose of the existing fossil fuels taxes is to earmark the revenue for specific projects explicitly mentioned in the tax laws. The revenue from the customs duty and Petroleum Tax is earmarked to finance various programs to secure stable supply of petroleum and to develop and introduce alternative energy sources. On the other hands, the revenue from the excise taxes on Gasoline, Light Oil, Jet Fuel and LPG is earmarked to finance road and/or airport construction.

When we take the aggravation of environmental situation with respect to CO₂ emissions into consideration, a green tax reform to abate the emissions would be desired. A greening of tax systems may be defined as the integration of environmental concerns into the design of tax systems (OECD, 1997: 8). Yokoyama (1997) examined the effect of a green tax reform, which converts the existing fossil fuels taxes or implicit carbon taxes into pure carbon taxes under the condition of revenue neutral, on the reduction of CO₂ emissions in Japan. The pure carbon taxes means the specific taxes that are imposed on all types of CO₂ emissions sources at a rate of a fixed amount of money per unit of carbon. And the tax rate per unit of each fossil fuel is determined on the quantities of carbon contained in the fossil fuel. A result of the examination is that the tax reform could abate effectively CO₂ emissions, under the assumption that price elasticities on the demand of the fossil fuels are the same.

As OECD (1997:23) points out, as energy or fossil fuels combustion is a major sources of pollution and of tax revenue, the restructuring of energy or implicit carbon taxes is one of the most promising paths to green tax reform. Our concern is to explore which restructuring of implicit carbon taxes is most desired, and whether or not carbon taxes should be additional to the existing implicit carbon or fossil fuels taxes. This paper will develop Yokoyama (1997) to change the assumption of the same price elasticity on the demand of the fossil fuels and to suggest an answer for such questions.

The purpose of this paper is to explore how CO₂ emissions would change when the existing implicit carbon taxes, excepting the customs duty and Petroleum Tax, are converted into the pure carbon taxes under the following assumptions:

1) The tax base covers all the fossil fuels.
2) The tax rates are determined based on the quantities of carbon contained in various fossil fuels.
3) The total tax revenue from fossil fuel taxes is kept unchanged after the tax reformation.
(4) The price elasticities on the demand of the fossil fuels are exogenously given.

2. The Model

2.1. Price, Quantity and CO₂ Emissions under the Implicit Carbon Tax

We assume that a supply curve of any kind of fossil fuels is horizontal because Japan has almost no domestic production of fossil fuels and may be a small country of which transaction does not change the world price. On the other hand, a demand curve of each fossil fuel is assumed to be of an ordinary shape and that the own price elasticity is constant. The supply and demand functions are defined as equations (1) and (2).

\[
\begin{align*}
\text{(1) Supply: } & \quad P = P_0 \\
\text{(2) Demand: } & \quad Q = AP^{-e}
\end{align*}
\]

Now let's calculate the change of the price and quantity in the transaction of a fossil fuel when \( t \) Yen per a unit quantity of this fossil fuel is imposed as the specific tax. The price and quantity after tax are expressed in equations (3) and (4).

\[
\begin{align*}
\text{(3) Price after tax: } & \quad P_t = P_0 + t \\
\text{(4) Quantity after tax: } & \quad Q_t = Q_0 - t \frac{dQ}{dp} = Q_0 - te \frac{Q_0}{p_0}
\end{align*}
\]

where, \( P_0 \) is the price before tax, \( t \) is the tax rate, \( Q_0 \) is the quantity before tax, and \( e \) is the price elasticity of the fossil fuel.

Since price and quantity before tax are naturally not observable, they must be inferred based on the market condition as assumed. The quantity before tax is calculated from equation (4) as follows:

\[
\text{(5) Quantity before tax: } \quad Q_0 = \frac{P_0 Q_t}{P_0 - et}.
\]

The revenue from this taxation is shown by

\[
\text{(6) Tax revenue: } \quad R_t = t Q_t.
\]

Therefore, the effect of CO₂ reduction \((dC)\) under the existing implicit carbon tax is expressed in equation (7) when carbon contained in a unit quantity of this fossil fuel is \( Z \).

\[
\text{(7) CO₂ reduction under the implicit carbon tax: } \quad dC = Z \cdot (Q_0 - Q_t)
\]
The total abatement effect of the existing implicit carbon taxes is the simple summation of \( dC \) inferred for each fossil fuel.

2.2. Price, Quantity and \( \text{CO}_2 \) Emissions under the Pure Carbon Tax

The tax rates per unit of fossil fuels under the pure carbon tax are proportional to the quantities of carbon contained in them. We think of the case where the revenue from the pure carbon tax is the same as that from the implicit carbon taxes. The tax rate of a fossil fuel under the pure carbon tax can be obtained as follows. If the specific tax rate of the pure carbon tax is \( x \) Yen per 1 kg of carbon, then the tax rate per unit of a fossil fuel, \( t_c \), is shown by

\[
(8) \quad \text{Tax rate under the pure carbon tax:} \quad t_c = Zx.
\]

The quantity after introduction of the pure carbon tax, \( Q_c \), is expressed in the equation (9) by adopting the equation (4).

\[
(9) \quad \text{Quantity after the carbon tax:} \quad Q_c = Q_0 - \frac{dQ}{dp} Zx = Q_0 - e \frac{Q_0}{p_0} Zx
\]

Therefore the revenue of the pure carbon tax on the fossil fuel, \( R_c \), is calculated as follows:

\[
(10) \quad \text{Revenue of the pure carbon tax:} \quad R_c = Q_c Zx = Q_0 Zx - e \frac{Q_0}{p_0} Z^2 x^2
\]

Since the total revenue from the pure carbon taxes imposed on fossil fuels must be the same as that from the implicit carbon taxes, the specific tax rate of the pure carbon tax \( (x) \) can be derived as a solution of the following quadratic equation:

\[
(11) \quad \sum \left( e \frac{Q_0}{p_0} Z^2 \right) \cdot x^2 - \sum (Q_0 Z) \cdot x + \sum R_t = 0
\]

Here we can calculate the effect of \( \text{CO}_2 \) reduction \( (dC^*) \) under the pure carbon taxes is shown by

\[
(12) \quad \text{CO}_2 \text{ reduction under the pure carbon tax:} \quad dC^* = Z \cdot (Q_0 - Q_c).
\]

3. Calculations

Table 1 (a) shows the derivation of \( \text{CO}_2 \) reduction by the existing implicit carbon taxes under the assumption that the price elasticity is 0.2 for all
fossil fuels. Table 1 (b) shows the derivation of CO₂ reduction by the existing implicit carbon taxes under the assumption of the price elasticities which Matsui (1979) and Bohi (1981) estimated. The price elasticity of Coal in Table 1 (b) is the short run one of coal for electric utilities estimated by Bohi (1981, Table 7-1:159), and other price elasticities are long run ones for industrial and transporting sectors which Matsui (1979, Figure3: 19-24) estimated using the data of 1965-1977. Because Matsui did not estimate the price elasticity of Jet Fuel we assume it is the same as that of BC Heavy Oil. The amount of carbon contained in a unit quantity of a fossil fuel, Z, is given in Table 1 by scientific data.

Table 1 (a) (b)

After deriving the specific tax rate of the pure carbon tax under revenue neutral from equation (11), we have calculated the effect of the pure carbon tax on CO₂ reduction (dC*). The results are shown in Table 2 (a) and (b), which are correspondent to the assumptions of price elasticities in Table 1 (a) and (b).

Table 2 (a) (b)

Table 3 summarizes the effects of the existing implicit and the pure carbon taxes on CO₂ reduction under revenue neutral in various assumptions of the price elasticities.

Table 3

The results are as follows:
1. When the price elasticity of every fossil fuel is equal, the converting the existing implicit carbon taxes into the pure carbon tax abates effectively CO₂ emissions.
2. The higher the same price elasticity, the more effectively converting into the pure carbon taxes abates CO₂ emissions.
3. But when the price elasticities of fossil fuels are different each other as Matsui (1979) and Bohi (1981) estimated and the price elasticity of Gasoline is relatively high, the converting the existing implicit carbon taxes into the pure carbon tax increases CO₂ emissions.

4. Consideration

The results show explicitly that it depends on the assumptions of the price elasticities of fossil fuels whether or not the converting the implicit into pure carbon taxes under revenue neutral abates CO₂ emissions. Especially when the price elasticity of gasoline is relatively high, the conversion from the implicit into pure carbon taxes under revenue neutral might not be desirable. Jones (1993: 687) points out, however, that while there are various estimations of the long run price elasticities ranging from 0.25 to 0.56, his estimation in the United States is 0.17. On the other hand, Bentzen and Engsted (1996) show that the long run price elasticity is 0.341
in their comment on Jones (1993). Table 3 shows also two cases of assuming that the price elasticities of gasoline are 0.170 and 0.341 instead of 0.4783 by Matsui (1979) and other elasticities are the same as in the case of Matsui and Bohi. Both cases show that conversion of the existing implicit carbon taxes into the pure carbon tax abates CO\textsubscript{2} emissions. In any case, we will have to estimate more correctly the price elasticity of gasoline in restructuring the existing implicit carbon taxes.

If the price elasticity of gasoline is relatively high as Matsui (1979) estimated, then the existing implicit carbon taxes in Japan have more effectively abated CO\textsubscript{2} emissions than the pure carbon tax would under revenue neutral. In this case, therefore, under the condition of the same additional revenue, proportionately increasing the rates of the existing implicit carbon taxes might be better than introducing a new pure carbon tax in addition to the existing taxes.

When the external marginal cost per unit of CO\textsubscript{2} emissions is constant it is considered to be reasonable to impose a pure carbon tax on all fossil fuels at a uniform rate per unit of carbon. How should we deal with the implicit carbon taxes in implementing a green tax reform? Put differently, how should we set the real tax rates of a carbon tax in the reform?

There are several options of the green tax reform within energy taxes to enhance the reduction of CO\textsubscript{2} emissions as follows:

1. Tax reform with revenue neutral
   (1) Converting the implicit carbon taxes to the pure carbon tax which imposes on all fossil fuels at a uniform rate per unit of carbon
   (2) Changing the excise tax on the fossil fuel with the lowest price elasticity to that on the fossil fuel with the highest elasticity

2. Tax reform with additional revenue
   (1) Introducing a new pure carbon tax which imposes on all fossil fuels at a uniform rate per unit of carbon, in addition to the existing implicit carbon taxes
   (2) Increasing proportionately the tax rates of the existing implicit carbon taxes
   (3) Introducing new fossil fuels taxes with different tax rates in addition to the existing implicit carbon taxes, to build an integrated pure carbon tax by combining the new with existing taxes
   (4) Increasing the excise tax on the fossil fuel with the highest price elasticity while others are unchanged
   (5) The two options, which are mentioned in the tax reform with revenue neutral, are also considerable if they lead to the additional revenue.

What we must consider is criterion of choosing among the options. The first criterion is the maximizing the reduction of CO\textsubscript{2} emissions subject to that the revenue from energy taxes is given. The second criterion is the maximizing the benefits from reducing the deadweight loss due to abating CO\textsubscript{2} emissions subject to that the target of abating amount of CO\textsubscript{2} emissions is given. The third criterion is the maximizing the possibility of public acceptance of the green tax reform, especially by businesses that rely heavily on energy in their production processes and are sensitive to the international competitiveness, subject to that the target of abating amount of CO\textsubscript{2} emissions is given.
The actual carbon taxes in Denmark, Finland, the Netherlands, Norway and Sweden, are not correctly the pure carbon tax, since Norway has different tax rates and others have principally a uniform tax rate but all have either exemptions or tax preferences. For example, the CO\textsubscript{2} tax in Denmark is not imposed on gasoline, natural gas and biofuels, and tax reductions can be applicable to businesses that rely heavily on energy in their production processes. The experiences of carbon taxes in these countries suggest that the criterion of choosing the green tax reform options is the third.

5. Concluding Remarks

This paper have explored the abating effects of CO\textsubscript{2} emissions by the green tax reform which converts the existing implicit carbon taxes into the pure carbon taxes under the condition that the total tax revenue from fossil fuel taxes is kept unchanged after the tax reform. The results we got are as follows:

1. When the price elasticity of every fossil fuel is equal, the converting the existing implicit carbon taxes into the pure carbon tax abates effectively CO\textsubscript{2} emissions.
2. The higher the same price elasticity, the more effectively converting into the pure carbon taxes abates CO\textsubscript{2} emissions.
3. But when the price elasticities of fossil fuels are different each other as Matsui (1979) and Bohi (1981) estimated and the price elasticity of Gasoline is relatively high, the converting the existing implicit carbon taxes into the pure carbon tax increases CO\textsubscript{2} emissions.

The results induce us to consider the options of the green tax reform within energy taxes to enhance the reduction of CO\textsubscript{2} emissions, and alternative criteria of choosing among the options. The actual green tax reforms of introducing carbon taxes in the Northern European countries seem to be chosen by the criterion of maximizing the possibility of public acceptance of the green tax reform subject to that the target of abating amount of CO\textsubscript{2} emissions is given.

There are, however, other two criteria of choosing the options of the green tax reform within energy taxes to enhance the reduction of CO\textsubscript{2} emissions; one is the criterion of maximizing the reduction of CO\textsubscript{2} emissions subject to that the revenue from energy taxes is given, and the other is the maximizing the benefits from reducing the deadweight loss due to abating CO\textsubscript{2} emissions subject to that the target of abating amount of CO\textsubscript{2} emissions is given. We will have to estimate correctly the price elasticities of all the fossil fuels in order to choose among the tax reform options based on the criteria. We hope that some participants in this world congress will estimate the price elasticities in their countries to suggest the best green tax reforms.

References


OECD (1997), *Environmental Taxes and Green Tax Reform*, OECD.


Figure 1

\[ h(x) \]

\[ -H(x) \]

MILIEU IMPERMEABLE

MILIEU POREUX

Sol

Aquifère

Eau Douce

Mer

Eau Salée

Figure 2

\[ V'(Y) \]

\[ C_\alpha(Y) \]

\[ (1) \]

\[ (2) \]

\[ (3) \]

\[ Y + \mu + \beta(\pi(Y) - x^0) + \beta Y d\pi/dY \]

\[ Y^{(1)} \]

\[ Y^{(2)} = Y^0 \]

\[ Y^{(3)} \]
### Table 1(a) CO2 Reduction under the Implicit Carbon Taxes

**Price Elasticity is 0.20 for all Energies**

<table>
<thead>
<tr>
<th>Price before Tax</th>
<th>Existing Tax</th>
<th>Price after Tax</th>
<th>Quantity after Tax</th>
<th>Price Elasticity</th>
<th>Quantification before Tax</th>
<th>Quantification after Tax</th>
<th>Reduction of Demand by Tax</th>
<th>Carbon</th>
<th>CO2 Reduction by Tax</th>
<th>Tax Revenue</th>
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<tr>
<td>P0</td>
<td>t</td>
<td>Pt</td>
<td>Qt</td>
<td>e</td>
<td>Q0</td>
<td>Qe</td>
<td>dQ</td>
<td>Z</td>
<td>dC</td>
<td>R</td>
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<td>46854</td>
<td>5,3800</td>
<td>102654</td>
<td>53,775</td>
<td>0.20</td>
<td>68,964</td>
<td>-15,189</td>
<td>0.6433</td>
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<tr>
<td>2 Gas (Light) Oil</td>
<td>47545</td>
<td>52100</td>
<td>79645</td>
<td>44,713</td>
<td>0.20</td>
<td>51,693</td>
<td>-6,980</td>
<td>0.7212</td>
<td>-5,034</td>
<td>1435,3</td>
</tr>
<tr>
<td>3 Jet Fuel</td>
<td>50000</td>
<td>26000</td>
<td>79645</td>
<td>4,000</td>
<td>0.20</td>
<td>4,668</td>
<td>-6,698</td>
<td>0.6669</td>
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<td>1040,0</td>
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<td>0</td>
<td>11492</td>
<td>4,599</td>
<td>0.20</td>
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<td>46589</td>
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<td>Total</td>
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<td></td>
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<td>-15,583</td>
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### Table 1(b) CO2 Reduction under the Implicit Carbon Taxes

**Price Elasticities are Based on Matsui(1979) and Bohi(1981)**

<table>
<thead>
<tr>
<th>Price before Tax</th>
<th>Existing Tax</th>
<th>Price after Tax</th>
<th>Quantity after Tax</th>
<th>Price Elasticity</th>
<th>Quantification before Tax</th>
<th>Quantification after Tax</th>
<th>Reduction of Demand by Tax</th>
<th>Carbon</th>
<th>CO2 Reduction by Tax</th>
<th>Tax Revenue</th>
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<tr>
<td>P0</td>
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<td>Qe</td>
<td>dQ</td>
<td>Z</td>
<td>dC</td>
<td>R</td>
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<tr>
<td>1 Gasoline</td>
<td>46854</td>
<td>5,3800</td>
<td>102654</td>
<td>53,775</td>
<td>0.4783</td>
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<td>79645</td>
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<td>79645</td>
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<td>0.6669</td>
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<td>4 Naphtha</td>
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8 LPG: 21265, 17500, 38765, 1,811, 0,7995, 5,293, -3,404, 0,8200, -2,856, 31,7
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