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Environmental Tax Reform, R&D Subsidies and CO_2 Emissions: View Double Dividend Hypothesis#

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ABSTRACT

This study investigated whether environmental taxes achieve the double dividend of coexistence of economic growth and environmental protection. The research method used dynamic industrial relations models to estimate the influence of environmental taxes influence on the economy and environment. The goal was to conduct an objective analysis with scientific data. The conclusions provide a clue indicating that environmental taxes could only be used to facilitate short-term coexistence between economic growth and environmental protection. Once entering the mid-term and long term, the lack of innovation and technical progress would eventually cause economic development and environmental protection to diverge, which is why studies are yet to reach a consensus. The results suggest that although using environmental taxes to promote economic development and environmental protection can achieve the double dividend in the short term, in the midterm, the first dividend disappears unless a solution for improved energy efficiency and technical innovation can be determined immediately. Furthermore, to sustain its economic development and environmental protection efforts, Taiwan must first optimize its industrial structure, which can only be achieved through advanced research and development.

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1. INTRODUCTION

In recent years, economic growth in Taiwan has faced increasing uncertainty in terms of adverse manufacturing conditions caused by escalating energy prices because of limited natural energy and almost total reliance on imports. Since 2007, the rising international crude oil price has led to a sharp increase in costs (Hong et al., 2012). Numerous studies have indicated that the fluctuating energy process has caused tremendous economic losses because of the overdependence on energy consumption for economic growth (Hamilton, 1983). Therefore, the stability in energy prices is a critical factor that influences economic growth (Huang et al., 2015a, 2015b).

In addition to the high international crude oil price, an unstable market exacerbates uncertainty surrounding a country's economic development. Although asymmetry exists between energy prices and energy demand (Ma et al., 2008), accelerating technological progress through research and development is an effective method of easing energy demand. A number of studies have investigated the relationship between energy price changes and technological progress through enterprise research and development and concluded that changes in energy production can be attributed to efficiency changes and technical changes. To maintain growth, the Taiwanese economy must strive toward improving efficiency in energy production and technological development. In particular, changes in energy intensity can be used to determine whether energy efficiency improves as the economy develops (Boone et al., 1996). Huang et al. (2015a, 2015b) suggested that since joining the World Trade Organization, Taiwan has not only experienced an increase in the intensity of imported energies but also increased sensitivity to energy prices, thereby indicating greater dependency on energy and the international market. Therefore, to achieve sustainable economic development, Taiwan must improve its energy-saving practices and energy efficiency as countermeasures against changes in the international economic environment and industrial structure. Double dividend environmental tax is noteworthy for achieving the double goal of economic development and environmental protection.

The present study adopted the concepts of short-term and mid-term double dividend environmental taxes as starting points for Taiwan's future economic development and environmental protection to investigate the degree of influence environmental tax could have on corporate goods prices and consumer prices. Price changes can cause changes in demand, which in turn can alter the volume of CO_2 emissions. Furthermore, as economic growth and employment increases are two indicators of the second dividend, an additional goal of the present study was to conduct an empirical analysis of scientific evidence of how environmental tax affects these two indicators.

2. LITERATURE REVIEW

Tullock (1967) proposes a tax reform to levy heavy taxes on "bads" such as pollution while simultaneously abating taxes on goods to reduce distortionary taxation and effectively achieve the double dividend. This proposal has been supported by numerous subsequent studies.

Nichols (1984) believed that income taxes could be replaced by revenue from environmental taxes, constituting a neutral fiscal policy to exact the double dividend. "Pigouvian taxes" are extremely heavy-handed tax policies that can distort market prices. Hence, under the tax interaction effect of environmental taxes, environmental taxes are superior to income taxes under the same tax rate. Lee and Misiolek (1986) propose an optimal environmental pollution tax rate to maximize the double dividend and further the development of conventional Pigouvian taxes.

Pearce (1991) argues that a government should adhere to tax neutrality to mitigate the effects of distortionary taxation, thereby reducing the distorted costs of preventing environmental pollution and tax deduction and facilitating the double dividend. To gain a clearer understanding of the double dividend, several studies have used various hypotheses to test its validity.

The validity of the double dividend is a controversial topic. Schob (1997) proposes that the origin of the controversy primarily lies in the definition of the second dividend in environmental taxes. The double dividend of environmental protection and economic growth is dependent on the effectiveness of increasing, abating, and subsidizing specific types of tax.

Jasen and Klaassen (2000) suggest that under the influence of the double dividend, the impact of adjusted tax on the economy is insignificant. This view has been supported by a number of studies. Jasen and Klaassen (2000) further notice the nonsignificant but positive impact on employment and estimate that 146,000–335,000 jobs would be created. Bruvoll and Bodil (2004) observe a significant impact of carbon tax on energy consumption in Norway. Specifically, carbon tax initiated a trend of decreasing energy intensity that was responsible for a 1.3% drop in 1999. Moreover, carbon tax caused increases in gasoline and heating oil prices of 7.6% and 17%, respectively, which led to 4.2% and 6.2% decreases in household consumption of these fuels, respectively. Reduced energy consumption, which can be referred to as lower CO_2 emissions, is precisely the first dividend in the double dividend hypothesis. Sterner (2007) verifies this association between the two phenomena by observing that levying fuel taxes facilitates reductions in energy consumption and gas emissions.

Shah and Bjorn (1992) suggest that in some countries, raising profit tax and overall environmental taxes yields greater improvements in social welfare. Many countries have improved their social welfare systems in this manner and the effectiveness of this practice is particularly noticeable in developing countries. Welsch and Ehrenheim (2004) contend that although energy taxes have a negative impact on a country's economy, they reduce CO_2 emissions and mitigate pollution. Roson (2003) suggests that although imposing energy tax to abate earned income tax does not achieve the double dividend, if used to reduce capital gains taxes, it will promote economic growth and yield a positive impact on social welfare. Chiroleu and Fodha (2006) assert that the effectiveness of environmental taxes is limited by the scale of a country's capital deposit and elasticity of intertemporal substitution and believe that the long-term double dividend can be achieved. In addition, Glomm et al. (2008) verify that such a double dividend is possible.

The literature review indicates that researchers are yet to reach a consensus on the double dividend of environmental taxes, which is indicative of the diversified opinions in related studies and normal in the field of social science. However, these studies have employed various research methods and models to tackle the topics they have explored. The present study is no exception.

3. EMPIRICAL MODELS

This study estimates the double dividend hypothesis based on data from the Central Academic Advisory Committee (2014). Following Miyazawa (2002) and Hong et al. (2017), the dynamic input-output model could be constructed as follows:

3.1. Dynamic Industrial Relations Models

$$X(t)=[I-(I-M)A)]^{-1}[(I-M)F^d+E] \quad (1)$$

Where

A: is the input coefficient matrix (n×n)

F^d: is the amount of the domestic final demand for industry

M: represents the diagonal matrix of import coefficient (n×n)

I: is the identity matrix (n×n)

Where

$$M_i = m_i(\sum_{j=1}^{n} a_{ij} X_j + F_i^d), i = 1, 2, \cdots n$$

where

$$m_i = \frac{M_i}{\left(\sum_{j=1}^{n} a_{ij} X_j + F_i^d\right)}, i = 1, 2, \cdots n$$

We compiled the following equilibrium equations for the dynamic input-output model:

$$X(t)=AX(t)+I(t)+F(t)=AX(t)+K[X(t+1)-X(t)]+F^d(t) \quad (2)$$

$$X(t+1)=[K^{-1} (I-A-C)+I]X(t) \quad (3)$$

We developed a dynamic industry-related model, where consumption (C) and investment (K) were used as two endogenous variables. Assuming *D=I-A-C*, the dynamic model can be written as

$$X(t+1)=(K^{-1} D+I) [I-(I-M)A)]^{-1} [(I-M) F^d+E] \quad (4)$$

3.2. Measurement of the Persons Employed

Let Leontief inverse matrix$(K^{-1} D+I) [I-(I-M)A)]^{-1}be\Gamma^{dynamic}$

$$\delta L_i = \left\{\left(I - \bar{M}\right)\delta F_1^d + \Gamma^{dynamic}(I - \bar{M})(\delta F_1^d + \delta F_2^d)\right\} * H_i \quad (5)$$

H_i is the employment coefficient matrix.

3.3. Energy and Environment in Dynamic Industrial Relations Models

We developed a dynamic model that features investment as an endogenous factor to estimate electricity consumption and CO_2 emissions.

$$E_j^{CO_2}\Gamma^{dynamic}\left[\left(I - M\right)F + E\right] \quad (6)$$

$$CO_2\ Emissions = \underbrace{E_j^{CO_2}\left(I - M\right)\delta F_1^d}_{Direct\ Spillover} + \underbrace{E_j^{CO_2}\Gamma^{dynamic}\left(I - M\right)\delta F_1^d}_{First\ Indirect\ Spillover} + \underbrace{E_j^{CO_2}\Gamma^{dynamic}[\left(I - M\right)\delta F_2^d]}_{Second\ Indirect\ Spillover} \quad (7)$$

$$E_j^{CO_2} = \begin{pmatrix} e_1^{CO_2} & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & e_n^{CO_2} \end{pmatrix}, e_j^{CO_2} = \frac{CO_{2_j}}{x_j}, j = 1, 2 \ldots n$$

Where the emissions coefficient $e_j^{CO_2} = \frac{CO_{2_j}}{x_j}$, and $E_j^{CO_2}$ is the diagonal matrix of the elements of the emissions coefficients for various industries.

4. EMPIRICAL RESULTS

Hong et al. (2017) suggest that environmental taxes induce an increase in the price of commodities and a decline in demand, thereby causing CO_2 emissions to drop. In other words, this study used the short-term direct effect for an empirical analysis to determine whether the first dividend occurs.

This study assumes that revenue from environmental taxes are transformed into subsidies for environmental research and development, on which grounds the short- and mid-term economic spillover effects and effectiveness of creating employment opportunities are estimated to determine whether the second dividend occurs. The results are as follows.

4.1. Spillover Effect of Environmental Taxes and Reduction of CO_2 Emissions

The reduced amount in each industry is estimated and incorporated into the dynamic industrial relations model with the energy consumption coefficients to estimate the short-term reduction in CO_2 emissions. The results are shown in Table 1.

The overall short-term reduction in CO_2 emissions is 3,415,171.48 metric tons, of which the greatest contributor is the service industries, which at 1,508,988.46 metric tons contributed 44.18% of the total. After comparing the reduction in CO_2 emissions and decline in demand, the significant gap between their respective proportions seems to be caused by the service industries' low energy intensity. Another noteworthy example is the chemical industries, which exhibits a mere 3.10% reduction in demand but a disproportional 826,756.86-metric-ton short-term reduction in CO_2 emissions, which amounts to 24.21% of the total reduction in CO_2 emissions; this can be attributed to the high energy intensity of the chemical industries. Therefore, according to Tables 2 and 3, environmental taxes induce the first dividend in the short term.

4.2. Economic Spillover Effect of Research and Development Subsidies

If the government uses tax revenue to subsidize environmental research and development, the economic benefits estimated using the proposed research are as shown in Table 2.

The economic spillover effect consists of production-induced added value, gross-induced added value, and earned income–induced added value. Production-induced added value refers to the economic value of merchandise. Gross-induced added value is the production remuneration received by the industries (corporations). Earned income–induced added value refers to wages for labor. The results indicate that the economic spillover effect (direct effect + first spillover + second spillover) of the NT$ 9,160 billion spent on environmental research and development yields a total economic benefit of approximately NT$ 1.29 trillion, of which approximately NT$ 6,363.64 billion serves as pretax remuneration for corporations and NT$ 3,607.02 billion was labor income.

The service and machinery industries enjoy the greatest benefits from raw materials with approximately NT$ 1,602.09 billion and 1,566.96 billion, respectively. Regarding the first spillover, the greatest beneficiary is the infrastructure industries with approximately NT$ 89.57 billion. Notably, three sectors exhibited negative growth, namely the iron and

Table 1: Reduction in CO_2 emissions

Section	Reduction in CO_2 emissions (metric tons)	%	Reduction ranking
Agriculture-related industries	292,206.17	8.56	4
Light industry	73,634.65	2.16	6
Chemical industry	826,756.86	24.21	2
Iron and Non-ferrous industries	19,659.57	0.58	7
Machinery- related industries	219,682.41	6.43	5
Infrastructure industry	474,243.34	13.89	3
Service-related industries	1,508,988.46	44.18	1
Total	3,415,171.48	100.00	

Unit: Metric tons

Table 2: Economic spillover effect of R&D subsidies

Economic spillover	Production-induced added value	Gross-induced added value	Income–induced added value
Direct effect	9,160.00	5,279.82	2,962.34
First spillover	2,603.00	702.21	408.44
Second spillover	1,104.33	381.70	236.24
Total	12,867.24	6,363.64	3,607.02

Unit: Billion. R and D: Research and development

Table 3: CO_2 emissions caused by R&D subsidies

Section	Direct effect (short-term)	First spillover (mid-term)	Second spillover (mid-term)	Total (%)
Agriculture-related industries	5,623.87	−84,673.76	169,771.90	90,722.01 (1.25)
Light industry	26,717.98	−6253.4404	23,591.21	44,055.75 (0.61)
Chemical industry	1,215,015.56	1,445,846.19	394,447.65	3,055,309.39 (42.05)
Iron and Non-ferrous industries	43,508.44	−26,385.47	5610.6832	22,733.65 (0.31)
Machinery- related industries	556,658.24	251,341.61	162,232.58	970,232.42 (13.35)
Infrastructure industry	181,435.33	1,599,372.73	5170.5452	1,785,978.60 (24.58)
Service-related industries	451,127.53	490,101.13	355,494.65	1,296,723.31 (17.85)
Total	2,480,086.95	3,669,348.89	1,116,319.22	7,265,755.05 (100)

Unit: Metric tons. R and D: Research and development

noniron industries (NT$ −74.27 billion), light industry (NT$ −17.60 billion), and agriculture industries (NT$ −74.27 billion). Regarding the second spillover, the machinery industries exhibit the greatest growth and the three sectors with negative growth in the first spillover have positive economic benefits. As a whole, the machinery and service industries have the greatest economic benefits with 36.00% and 33.69% of the overall amount, respectively.

4.3. Job Opportunities Created by Research and Development Subsidies

In addition to economic growth, more job opportunities can serve as an indicator of the second dividend of the double dividend. The estimation results obtained using the employment model for job opportunities in each industry created by research and development subsidies are shown in Table 4.

The most prominent short- and mid-term effects on employment occur in the service industries with 133,571 additional job opportunities accounting for 49.60% of the total increase, which indicates that the current industrial structure in Taiwan is still dominated by the service industries. The next most prominent effects are in the machinery and infrastructure industries, accounting for 59,384 and 30,942 job opportunities or 22.05% and 11.49%, respectively. By contrast, the labor intensive industries have significantly fewer new job opportunities. Based on the employment spillover coefficients, the iron and noniron industries,

Table 4: Job opportunities created by R&D subsidies

Section	Job opportunities created (person)	Percentage (%)
Agriculture-related industries	7,365	2.73
Light Industry	6,128	2.28
Chemical industry	28,231	10.48
Iron and Non-ferrous Industries	3,682	1.37
Machinery- related industries	59,384	22.05
Infrastructure industry	30,942	11.49
Service-related industries	133,571	49.60
Total	269,304	100.00

Unit: Person. R and D: Research and development

light industry, and agricultural industries comprise 1.37%, 2.28%, and 2.73% of the total increase, respectively, or 6.38% combined, which indicates that research and development subsidies have a relatively low influence on traditional industries.

4.4. CO_2 Emissions Caused by Research and Development Subsidies

The research and development activities of corporations yield CO_2 emissions. Table 5 shows that there were 2,480,086.95 metric tons of CO_2 emissions in the short term. A comparison with Table 3 shows that the reduction (−3,415,171.48 metric tons) was greater than the increase, which suggests that in the short term,

Table 5: Economic spillover effect of R&D subsidies

Section	Direct effect	First spillover	Second spillover	Total (%)
Agriculture-related industries	7.72	−8.42	160.37	159.67 (2.10)
Light Industry	75.21	−17.60	66.41	124.01 (1.63)
Chemical industry	417.94	497.34	135.68	1,050.95 (13.85)
Iron and Non-ferrous industries	122.47	−74.27	15.79	63.99 (0.84)
Machinery- related industries	1,566.96	707.51	456.68	2,731.15 (36.00)
Infrastructure industry	87.81	895.67	−81.97	901.51 (11.88)
Service-related industries	1,602.09	602.73	351.33	2,556.16 (33.69)
Total	3,880.20	2,602.96	1,104.29	7,587.45 (100)

Unit: Billion. R and D: Research and development

environmental taxes would induce the first dividend in the form of a 935,084.53 metric ton reduction in CO_2 emissions.

After the economic spillover initiated by research and development came into effect, mid-term CO_2 emissions account for 3,669,348.89 metric tons after the first spillover and 1,116,319.22 metric tons after the second spillover. The combined amount of CO_2 emissions caused directly by research and development activities and both spillovers is 7,265,755.05 metric tons, which far surpasses the short-term reduction. This suggests that the first dividend would be negated in the midterm.

5. CONCLUDING REMARKS

Taiwan is facing difficulties in industrial structural reform, economic development, and environmental protection, all of which are pressing issues that require immediate attention. Although numerous studies have analyzed these issues using the EKC theory, double dividend theory, and decoupling theory, none have convinced others or achieved a consensus. This is indicative of a difference of opinions based on economic and environmental issues that is yet to be resolved. Simultaneously attending to the economy and environment is extremely difficult and before it is possible, one issue must first be solved: The upgrade of the industrial structure. This issue is key to determining a country's success in achieving an optimized industrial structure. Part of the industrial structure can be upgraded in the short term but its optimization requires a long time; hence, it is a long-term issue for which research and development plays a pivotal role. Therefore, the present study sets environmental protection in the form of environmental taxes as the target for short-term analysis and investigates the mid-term effect of research and development subsidies on economic development and environmental protection. Based on such a premise, this study establishes industrial relations price models to analyze the influence of short-term price changes on consumption and uses dynamic industrial relations models and environmental industrial relations models to analyze short- and mid-term economic development and CO_2 emissions to verify the validity of the double dividend theory. From the empirical results, the following conclusions are drawn:

1. Empirical evidence suggests that environmental taxes can create the first and second dividend in the short term. The first dividend is a net reduction of 935,084.53 metric tons in CO_2 emissions and the second dividend is NT$ 9,160 billion worth of economic growth.
2. The 7,265,755.05-metric-ton mid-term increase in CO_2 emissions far surpasses the reduction of 3,415,171.48 metric tons in the short term, thereby negating the first dividend. In addition, the ongoing economic spillover creates approximately NT$ 12,867.24 billion worth of economic growth, 36% of which is contributed by the machinery industries.
3. Regarding industry, research and development subsidies cause the highest CO_2 emissions in the chemical industries, accounting for 42.05%. By contrast, these subsidies yield the biggest reductions in CO_2 emissions in the service industries with 44.18%, which indicates that the increase and reduction of CO_2 emissions in an industry vary depending on the environmental taxes and subsidies.
4. A total of 269,304 job opportunities have been created, of which the greatest contribution is made by the service industries, accounting for 49.60%.
5. These findings verify that although using environmental taxes to promote economic development and environmental protection can achieve the double dividend in the short term, the first dividend disappears in the midterm unless a solution to improve energy efficiency and technical innovation can be determined immediately. Furthermore, for Taiwan to sustain its economic development and environmental protection efforts, it must first optimize its industrial structure, which can only be achieved through research and development.

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