International Journal of Economics and Financial Issues

ISSN: 2146-4138

available at http: www.econjournals.com

International Journal of Economics and Financial Issues, 2018, 8(5), 21-25.

Tax Rate Adjustment and Its Potential Impact on Price: An Application Mathematical Input-Output Price Spillover Model[#]

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ABSTRACT

For a long time the failure of the Transformation of the Industrial Structure and the impact of the financial crisis of 2008, Taiwan promoted tax reform to solve economic development and environmental protection, and the tax rate adjustment of business tax and energy tax became the focus of the tax reform. Empirical evidences suggests that raising business tax by 1% affects the price level, with increases in the corporate goods price index (CGPI) and consumer price index (CPI) of 1.9474% and 1.37%, respectively, although both remain under 2%. The results of the study found that CGPI and CPI change in energy tax, the sectors affected the most of the chemical industries (4.23%) and service industries (4.04%).

Keywords: Tax Rate Adjustment, Price Spillover, Mathematical Input-Output Price Spillover Model
JEL Classifications: H2, D57, Q4

Special thanks to the Ministry of Science and Technology of Taiwan. This research is supervised under the funding of the ministry project MOST 106-2410-H-324-001.

1. INTRODUCTION

After the financial crisis of 2008, Taiwan's economic growth has slowed down, expanding its fiscal deficit, and the tax reform has become a solution. For example, increasing business tax is one of the tax reform policies. On the other hand, Taiwan passed the Greenhouse Gas Reduction and Management Act on June 16th, 2015. In July the same year, a goal to reduce CO2 emissions by 50% of the 2005 total by 2050 was announced. In September, the Executive Yuan announced in the Intended Nationally Determined Contribution a goal to reduce emissions by 20% by 2030, which was subsequently legalized in the Enforcement Rules of the Greenhouse Gas Reduction and Management Act, proclaimed on January 6, 2016. Since the country officially announced itself as a member of the global community against the greenhouse effect, the economic pattern it previously relied on requires suitable adjustments in line with the Greenhouse Gas Reduction and Management Act. Therefore, environmental taxes must be updated accordingly.

Therefore, economic development and environmental protection have become the future policy guidelines. Taiwan raises business tax to increase fiscal revenue, and levy energy tax to improve the environment. Since 2014-2017 period, Taiwan has proposed the adjustment of business tax and energy tax respectively. The increase of business tax and energy tax is to increase fiscal revenue as an investment in economic development, and on the other hand it can improve annuity funds and environmental protection.

However, the increase in the tax rate will cause price increases. Once inflation is triggered, it will increase the cost of consumption and production. As a result, it may have a negative impact on Taiwan's economy. This study will use the Mathematical Input-Output Price Spillover Model to estimate the impact of adjustments in business tax and energy tax on prices.

Based on the data estimated by the input-output price spillover model, the corporate goods price index (CGPI) and the consumer price index (CPI) are calculated. This study analyzes the price impact of fiscal policy based on changes in CGPI and CPI.

2. LITERATURE REVIEW

The impact of changes in tax rates on prices and demand has accumulated a lot of research results. Tax reform will change fiscal revenue, and will also change production costs and consumer prices, which will affect the consumption of goods. Therefore, the tax reform will have a much diversified effect, and we must carefully assess the necessity of tax rate changes.

Besley and Rosen (1998) argues that the prices of some commodities are affected by sales tax rates. This study found that some commodities are increase in sales taxes revenue of one dollar per unit increases the price by more than one dollar, and some commodities, the after-sales taxes price increases by exactly the amount of the tax. Hughes et al. (2006) studied the effect of changes in prices and income on oil demand. This paper compare the price and income elasticities of energy demand in two periods, and the short-run price elasticities differ.

Chetty et al. (2009) found that increases in taxes reduce alcohol consumption. In addition, Rivers and Schaufele (2015) studied the impact of Canadian carbon tax on gasoline demand. This study shows that carbon tax imposed caused a decline in short-run. As a result, carbon tax causes large consumer response to the tax. On the other hand, Canada's carbon tax reduces carbon emissions from gasoline consumption by 2.4 million tones. Dixit (1975) use consumer and producer surplus to explain the distortion effect of tax. Hong et al. (2012) Hong et al. (2012) analyzed the impact of rising oil prices on agribusiness production costs and price. The results indicate that agricultural sector overall, the increase in CPI (6.68%) was the highest, followed by producer price index (5.42%) and CPI (3.98%).

Bernard et al. (2014) analyzed the effect of gasoline and diesel demand on price and carbon tax. This study found that consumers have no significant difference between Carbon channels versus a standard excise tax. Sevestre et al. (2016) Study on the impact of soda tax on consumer prices in France. This study found that soda tax was passed through to the prices of the taxed beverages, and after 6 months, almost shifted to the prices of fruit drinks.

Hong et al. (2017) analyze crude oil intensity and the change in spillover effects of the crude oil price, using industry-related price model and factor decomposition model. The results of the study show that the increase in imported prices of crude oil caused a change in domestic price level.

3. EMPIRICAL MODELS

3.1. Mathematical Input-Output Model

The physical quantity bought by sector *j* to sector *i* when *j* produces the commodity *j* is denoted *xij*. This condition can be expressed as:

$$x_{11}+x_{12}+x_{13}+\cdots+x_1n+F_1+E_1=X_1+M_1$$

$$x_{21}+x_{22}+x_{23}+\cdots+x_2n+F_2+E_2=X_2+M_2$$

$$\vdots \ldots \vdots \ldots \vdots \ldots \vdots \ldots \vdots \ldots \vdots \ldots \vdots \ldots \vdots$$

$$x_{n1}+x_{n2}+x_{n3}+\cdots+x_{nn}+F_n+E_n=X_n+M_n \tag{1}$$

$$\sum \frac{n}{j=1} x_{ij} + F_i + E_i = X_i + M_i \; (i=1,2,\cdots n) \tag{2}$$

If coefficients are defines in physical terms, it is assumed that $a_{ij} = \frac{x_{ij}}{X_j}$ for all i and j are stable.

Where F is the amount of the domestic final demand for industry $(n\times 1)$. M represents the diagonal matrix of import coefficient $(n\times n)$. I is the identity matrix $(n\times n)$.

Where

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

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

This studies must be at equilibrium by row and by columns. By rows the accounting identity (2) becomes $\sum_{j=1}^{n} a_{ij}X_j + F_i + E_i = X_i + M_i$, that is:

$$X=[I-(I-M)A)]^{-1}\,[(I-M)F+E] \tag{3}$$

Where A is the input coefficient matrix $(n\times n)$.

$$A \equiv \begin{pmatrix} a_{11} & \cdots & a_{1n} \\ \vdots & \ddots & \vdots \\ a_{n1} & \cdots & a_{nn} \end{pmatrix}$$

3.2. Mathematical Input-Output Price Spillover Model

The hypothesis of Input-Output Price Spillover Model is fixed coefficients of the production functions of the industries. In the following section we explore extended price spillover models.

$$p_1x_{11}+p_1x_{12}+p_1x_{13}+\cdots+p_1x_1n+p_1F_1+p_1E_1=p_1X_1+p_1M_1$$

$$p_2x_{21}+p_2x_{22}+p_2x_{23}+\cdots+p_2x_2n+p_2F_2+p_2E_2=p_2X_2+p_2M_2$$

$$\vdots \ldots \vdots \ldots \vdots \ldots \vdots \ldots \vdots \ldots \vdots \ldots \vdots \ldots \vdots$$

$$pnx_{n1}+pn\,x_{n2}+pnx_{n3}+\cdots+pnxnn+pnFn+pnEn=pnXn+pnMn \tag{4}$$

and the quantity model (4) can be written as:

$$\sum_{j=1}^{n} p_i x_{ij} + p_i F_i + p_i E_i = p_i X_i + p_i M_i \ (i = 1, 2, \cdots n) \tag{5}$$

$$p_1 x_{11} + p_2 x_{21} + p_3 x_{31} + \cdots + p_n x_{n1} + V_1 = p_1 X_1$$
$$p_1 x_{12} + p_2 x_{22} + p_3 x_{32} + \cdots + p_n x_{n2} + V_2 = p_2 X_2$$

⋮…⋮…⋮…⋮…⋮…⋮…⋮…⋮

$$p_1 x_1 n + p_2 x_2 n + p_3 x_3 n + \cdots + pnxnn + Vn = pnXn \tag{6}$$

and the price model (6) can be written as:

$$P_1 a_1 j + P_2 a_2 j + \cdots\cdots + Pnanj + vj = Pj \ (j = {}_{1,2,3}, \cdots\cdots, n) \tag{7}$$

$$\begin{pmatrix} a_{11} & \cdots & a_{n1} \\ \vdots & \ddots & \vdots \\ a_{1n} & \cdots & a_{nn} \end{pmatrix} \begin{pmatrix} p_1 \\ \vdots \\ p_n \end{pmatrix} + \begin{pmatrix} v_1 \\ \vdots \\ v_n \end{pmatrix} = \begin{pmatrix} p_1 \\ \vdots \\ p_n \end{pmatrix} \tag{8}$$

$$A'P+V=P \tag{9}$$

$$P=[I-A']^{-1}V \tag{10}$$

$$P=[(I-A)^{-1})]'V \tag{11}$$

Where P is column vector of commodity prices. V is a column vector of value added per unit.

A' is the transpose of the technical input coefficients matrix.

$$A' \equiv \begin{pmatrix} \boldsymbol{a}_{11} & \cdots & \boldsymbol{a}_{n1} \\ \vdots & \ddots & \vdots \\ \boldsymbol{a}_{1n} & \cdots & \boldsymbol{a}_{nn} \end{pmatrix}, P \equiv \begin{pmatrix} p_1 \\ \vdots \\ p_n \end{pmatrix}, \mathrm{V} \equiv \begin{pmatrix} v_1 \\ \vdots \\ v_n \end{pmatrix}$$

When v1、v2⋯vn increase the increase of δv1、δv2⋯δvn, and will cause prices to rise together. So, $\delta p(t)$ can be written as follows:

$$p^{(t)}=p+(I+A'+A^{2\prime})+\cdots+A^{(t-1)\prime}\delta V \tag{12}$$

$$\delta p^{(t)}=(I+A+A^2+\cdots+A^{t-1})'\delta V \tag{13}$$

$$\lim(t\to\infty)\delta p^{(t)}=[(I-A)^{-1}]'\,\delta V \tag{14}$$

There are two types of input-output models, which are the competitive import and the non-competitive import models. Taiwan's import level influenced by the size of the domestic demand, we employ the competitive type of the input-output spillover model for Taiwan's trade oriented economy. So by rows the accounting identity (14) can be written as:

$$\delta P=([I-(I-\bar{M})A]^{-1})'\delta V \tag{15}$$

Where δP is the extent to which prices are increased by 1% (1.46) increase in business tax rate (energy tax). δV represents the transferability of a 1% (1.46) increase in business tax rate (energy tax).

3.3. The Establishment of CGPI and CPI Models

In the following section we explore extended CGPI and CPI, and can be written as:

$$\mathrm{CGPI} = \sum_{i=1}^{n} \delta P_i = \sum_{j=1}^{n} x_{ij} \Big/ \sum_{i}^{n}\sum_{j}^{n} x_{ij} \tag{16}$$

$$\delta\mathrm{CPI} = \sum_{i=1}^{n} \delta P_i \bullet Cp_i \Big/ \sum_{i}^{n} Cp_i \tag{17}$$

Where $\sum_{j=1}^{n} x_{ij}\ (i = 1, 2, 3, \ldots n)$ represents the intermediate sector. $\sum_{i}^{n} Cp_i\,(i = 1, 2, 3, \ldots n)$ represents the sum of private consumption expenditure ratio ($[\![\mathrm{Cp}]\!]_i$).

4. EMPIRICAL RESULTS

4.1. Scale of Commodity Price Increase

The scale of the economic impact of raising business tax by 1% refers to the degree of impact on commodity prices. Table 1 shows the changes in the corporate goods price indices (CGPIs) and CPIs of 166 industries induced by the raised business tax. Overall, the average CGPI and CPI increases are 1.9474% and 1.37%, respectively, which together cause a 3.3174% increase in commodity prices. Of the 23 sectors listed, the petrochemical plastic fibers industries exhibit the greatest CGPI increase with 1.0809%, which accounts for 55.50% of the total CGPI increase. The greatest CPI increases are those of 0.6451% in the wholesale and retail industries, which account for 47.09% of the total CPI increase.

The CGPI increase represents increases in the selling prices of commodities, which are reflected in the corresponding CPI increase. The difference between the CGPI and CPI increases represents the degree of cost shifted from corporations to consumers. A total of 11 sectors exhibit CGPI > CPI, which indicates a lower extent of cost shifting. These are mostly manufacturing industries with codes between 5 and 10, the most notable being the petrochemical plastic fibers industries, followed by the energy and mining industries. By contrast, 12 sectors exhibit CGPI < CPI, which indicates a higher extent of cost shifting. The most notable of these are the service and light industries, and wholesale and retail industries followed by the transportation, logistics, and warehousing industries.

4.2. Spillover Effect of Energy Taxes

The empirical analysis in the present study was conducted based on the assumption that energy taxes induce an increase in the price of commodities and a decline in demand, thereby causing CO2emissions to drop. This study estimates the impact of environmental taxes on prices, CGPI, and CPI (CPI; Table 2).

Overall, all prices exhibited increase considerably and the CGPI and CPI increase by 7.60% and 5.36%, respectively. The industries that exhibit the greatest CGPI increases are the chemical and service industries at 4.23% and 1.19%, respectively. Regarding

Table 1: The impact of business tax on prices

Sector	①→CGPI	②→CPI	①+②	①-②
Agricultural-related Industries	0.0193	0.0588	0.0781	−0.0395
Energy and mining-related industries	0.1112	0.0000	0.1112	0.1112
Food processing-related industries	0.0316	0.1144	0.1460	−0.0828
Textile and leather-related industries	0.0246	0.0298	0.0543	−0.0052
Wood pulp-related industries	0.0276	0.0044	0.0321	0.0232
Petrochemical plastic fiber-related industries	1.0809	0.0483	1.1292	1.0326
Glass cement non-ferrous-related industries	0.0524	0.0027	0.0551	0.0497
Metal-related industries	0.0987	0.0038	0.1024	0.0949
Semiconductor computer division-related industries	0.0454	0.0086	0.0540	0.0368
Power generation optical-related industries	0.0372	0.0097	0.0469	0.0275
Vehicle manufacturing-related industries	0.0152	0.0230	0.0382	−0.0078
Furniture-related industries	0.0083	0.0240	0.0323	−0.0157
Electric power water-related industries	0.0710	0.0088	0.0798	0.0622
Sewage resource recovery-related industries	0.0057	0.0001	0.0058	0.0056
Residential public construction-related industries	0.0132	0.0007	0.0138	0.0125
Wholesale and retail-related industries	0.1598	0.6451	0.8049	−0.4853
Transportation and storage-related industries	0.0778	0.1813	0.2592	−0.1035
Accommodation and catering-related industries	0.0088	0.0617	0.0705	−0.0529
Media information service-related industries	0.0081	0.0113	0.0194	−0.0032
Financial-related industries	0.0055	0.0138	0.0193	−0.0083
Real estate residential service-related industries	0.0048	0.0482	0.0530	−0.0434
Social health service-related industries	0.0028	0.0412	0.0439	−0.0384
Other service industries-related industries	0.0376	0.0302	0.0678	0.0074
Total	1.9474	1.3700	3.3174	0.5774

Unit: Percentage (%). $\delta\text{CGPI} = \sum_{i=1}^{n} \delta P_i = \sum_{j=1}^{n} x_{ij} / \sum_{i}^{n}\sum_{j}^{n} x_{ij}$; $\delta\text{CPI} = \sum_{i=1}^{n} \delta P_i \cdot Cp_i / \sum_{i}^{n} Cp_i$. CGPI: Corporate goods price index, CPI: Consumer price index

Table 2: The impact of energy tax on prices (short-term)

Sector	CGPI	CPI
Agriculture-related industries	0.634561 (3)	0.677767 (2)
Light industries	0.204187 (6)	0.133898 (5)
Chemical industries	4.230195 (1)	0.189123 (4)
Iron and non-ferrous industries	0.591022 (5)	0.025421 (7)
Machinery-related industries	0.620746 (4)	0.255235 (3)
Infrastructure industries	0.127205 (7)	0.037402 (6)
Service-related industries	1.193796 (2)	4.042457 (1)
Total	7.601713	5.361303

Unit: Percentage (%). (…) Parentheses represents the order of price increases.

$\delta\text{CGPI} = \sum_{i=1}^{n} \delta P_i = \sum_{j=1}^{n} x_{ij} / \sum_{i}^{n}\sum_{j}^{n} x_{ij}; \text{CPI} = \sum_{i=1}^{n} \delta P_i \cdot Cp_i / \sum_{i}^{n} Cp_i$.

CGPI: Corporate goods price index, CPI: Consumer price index

Table 3: Energy tax reduces industry demand

Sector	Demand reduction (billion)	Ranking (%)
Agriculture-related industries	97.937	2 (10.69)
Light industries	20.728	5 (2.26)
Chemical industries	28.438	4 (3.10)
Iron and non-ferrous industries	5.534	7 (0.60)
Machinery-related Industries	61.839	3 (6.75)
Infrastructure industries	16.896	6 (1.84)
Service-related industries	684.594	1 (74.74)
Total	915.966	100.00

CPI, the service and agriculture industries exhibit the greatest increases at 4.04% and 0.68%, respectively. Thus, the increased prices influence demand because although the effects observed vary based on consumer commodities, commodity consumption decreases.

Table 3 shows that taxed short-term effects cause the greatest decline in demand in the service industries at approximately NT$ 684.594 billion or 74.74% of the original demand. The second greatest drop is in the agriculture industries at approximately NT$ 97.937 billion. By contrast, the least affected industries are the iron and noniron and infrastructure industries at approximately NT$ 5.534 billion and 16.896 billion, respectively. The reduced demand shown in Table 3 is the result of raised prices caused by energy taxes and resulting in reduced CO_2 emissions.

5. CONCLUDING REMARKS

This study establishes a price spillover model to investigate the influence of raised business tax on commodity processes. Raising business tax by 1% influences the price level, thereby verifying that taxation can distort the pricing mechanism of the market. However, the results suggest that the influence is not particularly substantial. In addition, the results show that CGPI and CPI increase by 1.9474% and 1.37%, respectively. However, because price fluctuation occurs in the wholesale and retail industries, care should be taken to ensure that this does not continually cause increases in daily commodity prices, otherwise inflation occurs as a consequence. The price index for the circulation and consumption stages is increases by 3.3174%, which suggests that under the direct effects, consumer demand drops, thereby exerting a significant impact on the economy. In addition, gross added value, earned income, and the employment rate are reduced.

Imposing energy tax to cause prices to rise and consumer demand to drop: According to the estimated CGPI and CPI, the sectors affected the most are the chemical industries (4.23%) and service industries (4.04%), respectively, which implies that environmental taxes have varying impacts on corporations and consumers. The coexistence of economic development and environmental protection is a long-term issue that cannot be resolved through short-term policies. In particular, tax rate adjustments will distort prices, which may hinder economic development.

The above results show that the tax reform can increase tax revenue, but it also causes price fluctuations. Traditional economic theory believes that taxation distorts market mechanisms and excessive intervention in the market may also have negative economic impact. However, the problem of market failure makes national forces must intervene, especially the external diseconomy. It must be noted that whether the tax reform can effectively solve the economic development and environmental protection?

The conclusions of this study provide a clue that energy taxes can only benefit the coexistence of economic development and environmental protection in the short term. Upon entering the midterm or long term, the lack of innovation and technical progress eventually causes economic development and environmental protection diverge, which is why studies are yet to achieve a consensus. Industrial development in Taiwan is based on that of advanced countries, particularly the capacity for research and development, which is limited in Taiwan. Heated debates on adjusting the industrial structure have flared up since the 1980s, but even after three decades the problem remains, which indicates that Taiwan has never truly sensed the importance of research and development, hence the current imbalance in economic structure and industrial structure.

Policies for economic growth and environmental protection must be based on an optimized industrial structure. Two indicators of optimization are whether industries can fulfill the goals of high value and cleanness. High value is pivotal to economic growth, whereas cleanness governs the effectiveness of improving environmental quality. Both can be optimized through advanced technology. This study found that although environmental taxes can create the double dividend in the short term, sustainable economic growth and the environment are dependent on sustained investment in research and development. Therefore, the first step should be to establish indicators for research and development efficiency in each industry because the CO2 emissions coefficient and core technologies in each industry vary greatly depending on the characteristics and development of the industry in question. Therefore, thorough planning is required for the use of research and development subsidies for optimal returns.

This study only conducted short-term and mid-term empirical analyses with research models. Therefore, a suitable model for long-term analysis is yet to be developed. This problem must be solved by incorporating the investment coefficient (technical advancement indicator) of each industry into the research model to determine the changes in research and development by observing the investment of research and development subsidies, which constitutes a method for achieving the goals of high value and cleanness in economic growth and environmental protection, both of which are critical issues that require further investigation.

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