The Effects of E-scrap Supply Shocks on Recycling by the Non-Ferrous Metals Industry

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出版者	法政大学経済学部学会
journal or publication title	The Hosei University Economic Review
volume	88
number	4
page range	165-172
year	2021-03-20
URL	http://doi.org/10.15002/00024151

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1. Introduction

Recently, Japan have been faced with the problem of scarce resources utilisation such as non-ferrous metals. This metals are classified into one of exhaustible resources, which be used mostly on production processes of a manufacturing industry. However there is not enough for the industry to use non-ferrous metals around Japan. We greatly depend on the Import of metals from foreign countries. Accordingly Japanese economy is confronted with the stable supply of metals.

On the other hand non-ferrous metals are regarded as one of recycled resources. In fact non-ferrous metals can be generated by recycling of scrap materials; for example used personal computers, used mobile phones, and used home appliances which be commonly called as "E-waste (Electronic Waste) or E-scrap (Electronic Scrap)". Most of E-scrap generated in Japan have been exported to Asian countries for the purpose

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of reuse. Certainly International reuse of E-scrap is one of the effective approaches to establish an International Sound Material Circular Society around the world (See Yokoo and Kinnaman, 2011). International reuse of E-scrap inversely prevent the scarce resources from circulating around a domestic country. In short, we face the trade-off relationship between the resource circulations domestically and internationally.

In this study, we examine the implications of simultaneous equilibrium in three related markets; domestic E-scrap, foreign E-scrap, and composite inputs. We use the method of "equilibrium displacement modelling" (EDM) termed by Piggott (1992) which uses equations representing the demand and supply sides of each market. There are many applications of comparative static analysis to structural models of commodity markets to linearly approximate changes in prices and quantities and consequent changes in economic surplus from exogenous changes in demand, supply, or government intervention. This approach is also called "Muth Modeling" which Muth (1964) show how from an analysis similar to that of Hicks(1948) one can derive the elasticity of the industry supply schedule as well as the coefficients of other variables which appear in its supply schedule and in its factor demand schedules. Based on this approach we can derive the elasticities that show the effects of supply shocks of domestic and foreign E-scrap on the related markets.

2. Partial Equilibrium Model for a non-ferrous metals industry

Firstly we explain the non-ferrous metals industry's behavior with recycling activity. Second we derive the conditions for the equilibrium of the industry.

2.1. A non-ferrous metals industry's behavior with recycling activity

The model of this study is based on Brandow (1962), Muth (1964), and Floyd (1965) which is an extension of the one-product, two factor model developed by Allen (1938). Our model is specified with an output market for metals (q) and three factor markets for domestic E-scrap (w), foreign E-scrap (x), and the composite inputs (y) for labor or capital. We assume that these factors are separable from all other inputs. Assuming that a competitive non-ferrous metals industry using three factors of production to produce metals (or ingots) such as aluminum, copper, and lead, the production function for aggregate metal output is given by

$$q=Q(w, x, y). \quad (1)$$

This production technology is represented by

$$Q_w>0,\ Q_{ww}<0,\ Q_x>0,\ Q_{xx}<0,\ Q_y>0,\ Q_{yy}<0,\ Q_{wx}<0,\ Q_{wy}>0,\ Q_{xy}>0.$$

Moreover we assume that the amount of waste generation (z) depends on the quantities of each e-scrap inputs as follows;

$$z=Z(w, x, y). \quad (2)$$

This waste generation function is specified by

$$Z_w=b_W>0,\ Z_x=b_X>0,\ Z_y=-b_Y.$$

Therefore we can rewrite this function as

$$z=b_W w+b_X x-b_Y y. \quad (3)$$

Lastly the profit of non-ferrous metals industry is

$$\pi=pQ-p_W w-p_X x-p_Y y-p_Z z, \quad (4)$$

where p, p_W, p_X, p_Y, and p_Z are the price of a metal, a virgin material, domestic E-scrap, foreign E-scrap, the composite inputs, and the charge of waste disposal.

2.2. The equilibrium conditions within the non-ferrous metals industry

Then the equilibrium conditions within this industry can be described by the following set of three equations:

$$P(Q)Q_w = S^W(w, \alpha_W) + p_Z b_w, \quad (5)$$

$$P(Q)Q_x = S^X(x, \alpha_X) + p_Z b_X, \quad (6)$$

$$P(Q)Q_y = p_Y - p_Z b_Y, \quad (7)$$

where P (Q) is the demand function for the industry's output, $S^W(\cdot)$ and $S^X(\cdot)$ express the factor supply schedules facing the industry respectively, and α_W and α_X denote supply shift parameters for domestic and foreign E-scrap. Moreover we assume that $P_q<0$, $S^W{}_w>0$, $S^W{}_\alpha<0$, $S^X{}_x>0$, and $S^X{}_\alpha<0$.

3. Comparative Static Analysis

In this section, we make a comparative static analysis using the above equilibrium conditions to predict how a supply shock influences the quantities of metals, domestic E-scrap, and foreign E-scrap, or industry's profits.

At first our model defines a supply shock of E-scrap markets as a shift in these supply function respectively; $S^W{}_\alpha<0$ and $S^X{}_\alpha<0$. In other words, all other things being equal, this shifts decrease the amount of each E-scrap.

3.1. Effect of a domestic E-scrap supply shift

The effects of a shift in domestic E-scrap supply on market equilibrium are analyzed by differentiating equations (5) to (7) with respect to α_W, while α_X is held constant. This yields the following system of equations:

$$\begin{bmatrix} H_{11} & H_{12} & H_{13} \\ H_{21} & H_{22} & H_{23} \\ H_{31} & H_{32} & H_{33} \end{bmatrix} \begin{pmatrix} dw \\ dx \\ dy \end{pmatrix} = \begin{bmatrix} -S^{w}_{\alpha} \\ 0 \\ 0 \end{bmatrix} d\alpha_{W}, \tag{8}$$

where

$H \equiv H_{11}H_{22}H_{33} + H_{12}H_{23}H_{31} + H_{21}H_{32}H_{13} - H_{13}H_{22}H_{31} - H_{12}H_{21}H_{33} - H_{11}H_{32}H_{23}$

We can rewrite each Hii as the relevant elasticities;

$H_{11} = (p_{WZ}/w)[(\gamma_W/\varepsilon) + \delta_{WW}] - (p_W/w)(\eta_{WW})^{-1} < 0$

$H_{21} = H_{12} = (p_{XZ}/w)[(\gamma_W/\varepsilon) + \delta_{XW}] = (p_{WZ}/x)[(\gamma_X/\varepsilon) + \delta_{WX}] < 0$

$H_{31} = H_{13} = (p_{YZ}/w)[(\gamma_W/\varepsilon) + \delta_{YW}] = (p_{WZ}/y)[(\gamma_Y/\varepsilon) + \delta_{WY}]$

$H_{22} = (p_{XZ}/x)[(\gamma_X/\varepsilon) + \delta_{WW}] - (p_X/x)(\eta_{XX})^{-1} < 0$

$H_{32} = H_{23} = (p_{XZ}/y)[(\gamma_Y/\varepsilon) + \delta_{XY}] = (p_{YZ}/x)[(\gamma_X/\varepsilon) + \delta_{YX}]$

$H_{33} = (p_{YZ}/y)[(\gamma_Y/\varepsilon) + \delta_{YY}] < 0$

where we denote new valuables as follows;

$$\gamma_i \equiv (dQ/di)(i/Q_i) = Q_i(i/Q) > 0 \qquad (i = W, X, Y) \tag{9}$$

is the elasticity of production with respect to domestic E-scrap, foreign E-scrap, and composite inputs,

$$\varepsilon \equiv (dQ/dP)(P/Q) = (P_q)^{-1}(P/Q) < 0 \tag{10}$$

is the price elasticity of demand for metals,

$$\delta_{iiv} \equiv (dQ_i/di)(i/Q_i) = Q_{ii}(i/Q) \tag{11}$$

is the elasticity of marginal product with respect to domestic E-scrap, foreign E-scrap, and composite inputs,

$$\eta_{ii} \equiv (di/dpi)(p_i/i) = (S^{i}_{i})^{-1}(p_i/i) > 0 \tag{12}$$

is the factor price elasticity of supply of domestic E-scrap and foreign E-scrap.

Also we denote that p_{iZ} $p_i + p_Z b_i$. Then the effect of a domestic E-scrap supply shock on the quantity of domestic E-scrap demand

$$\partial w/\partial \alpha_w = (1/H)(H_{22}H_{33} - H_{32}H_{23})S^{W}_{\alpha}, \tag{13}$$

for the quantity of foreign E-scrap demand

$$\partial x/\partial \alpha_w = (1/H)(H_{32}H_{13} - H_{12}H_{33})S^{W}_{\alpha}, \tag{14}$$

and for the quantity of composite inputs demand

$$\partial y/\partial \alpha_w = (1/H)(H_{12}H_{23} - H_{22}H_{13})S^{W}_{\alpha}. \tag{15}$$

Moreover the effect of a domestic E-scrap supply shock on a non-ferrous metals industry's profit as follows;

$$d\pi/d\alpha_w = \Sigma[(PQ_i - p_i - p_z b_i) + (P_q QQ_i - S^i_i \cdot i)](di/d\alpha_w) - (S^w_\alpha \cdot i) \tag{16}$$

$$= \Sigma[p_{iz}\varepsilon^{-1} - p_i \eta_i{}^{-1})](di/d\alpha_w) - (S^w_\alpha \cdot i)$$

3.2. Effect of a foreign E-scrap supply shift

The effects of a shift in foreign E-scrap supply on market equilibrium are also analyzed by differentiating equations (5) to (7) with respect to α_X, while α_W is held constant. This yields the following system of equations:

$$\begin{bmatrix} H_{11} & H_{12} & H_{13} \\ H_{21} & H_{22} & H_{23} \\ H_{31} & H_{32} & H_{33} \end{bmatrix} \begin{pmatrix} dw \\ dx \\ dy \end{pmatrix} = \begin{bmatrix} 0 \\ -S^x_\alpha \\ 0 \end{bmatrix} d\alpha_X, \tag{17}$$

Then the effect of a foreign E-scrap supply shock on the quantity of domestic E-scrap demand

$$\partial w/\partial \alpha_x = (1/H)(H_{23}H_{31} - H_{12}H_{33})S^{X}_{\alpha}, \tag{18}$$

for the quantity of foreign E-scrap demand

$$\partial x/\partial \alpha_x = (1/H)(H_{11}H_{33} - H_{13}H_{31})S^{X}_{\alpha}, \tag{19}$$

and for the quantity of composite inputs demand

$$\partial y/\partial \alpha_x = (1/H)(H_{21}H_{13} - H_{11}H_{23})S^{X}_{\alpha}. \tag{20}$$

Moreover the effect of a foreign E-scrap supply shock on a non-ferrous metals industry's profit as follows;

$$d\pi/d\alpha_x = \Sigma[(PQ_i - p_i - p_z b_i) + (P_q QQ_i - S^i_i \cdot i)](di/d\alpha_x) - (S^x_a \cdot i) \tag{21}$$

$$= \Sigma[p_{iz}\varepsilon^{-1} - p_i \eta_i{}^{-1})](di/d\alpha_x) - (S^x_a \cdot i)$$

4. Concluding Remarks

This short paper has investigated the consequences of supply shocks of domestic and foreign E-scrap for the quantities of domestic E-scrap, Foreign E-scrap, composite inputs, and the non-ferrous metals industry's profits. We can show these effects as the elasticity of production, the elasticity of marginal product for these inputs, the price elasticity of metals demand, and the price elasticity of supply of domestic or foreign E-waste.

This model permits a coherent and comprehensive method of characterizing a supply shock and evaluating its effect on competitive input and output markets. We can apply this method to the other industry and extend this approach to multi market for outputs.

The model may be empirically useful in examining the effects of supply shocks either in an ex ante sense when parameters can be predicted and estimated, or as a basis for formulating econometric models to examine ex post effects of supply shocks.

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In this study, we examine the implications of the simultaneous equilibrium in three related markets; domestic E-scrap, foreign E-scrap, and composite inputs. We use the method of "equilibrium displacement modelling" (EDM), so termed by Piggott (1992), which uses equations representing the demand and supply sides of each market. Based on this approach we can derive the elasticities that show the effects of supply shocks of domestic and foreign E-scrap on the related markets.