科技部補助專題研究計畫成果報告
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資源回收政策再審思：廠商延伸性責任的實施

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中 華 民 國 105 年 10 月 18 日

中文摘要：考慮消耗性資源日益耗竭，資源回收已成為解決垃圾管理問題的一種重要管理工具。在廠商延伸性責任(Extended Producer Responsibility, EPR)的觀念下，臺灣於1998年在環保署下成立資源回收基金會，負責推動各種產品在使用過後報廢品（end of life）的回收。本計畫擬對廠商延伸性責任的實施，分別檢視產品鍊上的產品生產者、消費者、資源回收者的反應。
本計畫主要探討分析各類報廢品及一般資源垃圾的回收績效，並發展出數學模式，分析回收費或資源稅的徵收，對產品鍊上各角色（商品廠商、回收商以及消費者）行為的影響。本計畫為一年期計畫，至今為止，已經完成一篇論文，如附錄，已投稿國際期刊。尚有部分資料還在整理中，預計字在外來一年內，可以再完成1-2篇期刊論文，並考慮投稿於國際期刊。另外，本計畫的實施，也提供學生參與計畫，瞭解如何觀察問題，如何切入問題並加以解決。也讓學生有更多的機會與師長互動，對於培養學生的學術研究能力，應該會有相當大的助益。

中文關鍵詞：延伸性責任、回收績效、垃圾回收費、資源稅

英文摘要：Considering the continual reduction of exhaustible resources conservation, recycling is widely recognized as an important strategy to improve the environmental pressure. In 1998, Recycling Fund Management Board was established under the control of Taiwan EPA to be in charge of various activities in association with waste recycling. The major purpose of this project is to evaluate the performance of all the recyclables in Taiwan and to examine the impact of resources on the product producers and recyclers behaviors. In this project, we present a mathematical model to analyze the optimal resources level to encourage the product producer to redesign the packaging for the achievement of a more environmental friendly pattern.
In the past one year, an article is completed and submitted to an international journal. More papers can be completed in the coming year. The implementation of this project also yields some additional benefits including the training of research methods on students.

英文關鍵詞：extended producer responsibility, recycling performance, recycling fee, resource tax.

行政院國家科學委員會補助專題研究計畫 ■ 成 果 報 告
□期中進度報告

（計畫名稱）

資源回收政策再審思-廠商延伸性責任的實施

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共同主持人：
計畫參與人員： 謝伊婷、張家瑜、許雅雯、洪仲鈺、柯心詠

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執行單位：南華大學休閒環境管理研究所

中　華　民　國　105　年 10　月　23　日

資源回收政策再審思–廠商延伸性責任的實施

摘要

考慮消耗性資源日益耗竭，資源回收已成為解決垃圾管理問題的一種重要管理工具。在廠商延伸性責任(Extended Producer Responsibility, EPR)的觀念下，臺灣於 1998 年在環保署下成立資源回收基金會，負責推動各種產品在使用過後報廢品（end of life）的回收。本計畫擬對廠商延伸性責任的實施，分別檢視產品鍊上的產品生產者、消費者、資源回收者的反應。

本計畫主要探討分析各類報廢品及一般資源垃圾的回收績效，並發展出數學模式，分析回收費或資源稅的徵收，對產品鍊上各角色（商品廠商、回收商以及消費者）行為的影響。本計畫為一年期計畫，至今為止，已經完成一篇論文，如附錄，已投稿國際期刊。尚有部分資料還在整理中，預計字在外來一年內，可以再完成 1-2 篇期刊論文，並考慮投稿於國際期刊。另外，本計畫的實施，也提供學生參與計畫，瞭解如何觀察問題，如何切入問題並加以解決。也讓學生有更多的機會與師長互動，對於培養學生的學術研究能力，應該會有相當大的助益。

關鍵字：延伸性責任、回收績效、垃圾回收費、資源稅

Abstract

Considering the continual reduction of exhaustible resources conservation, recycling is widely recognized as an important strategy to improve the environmental pressure. In 1998, Recycling Fund Management Board was established under the control of Taiwan EPA to be in charge of various activities in association with waste recycling.

The major purpose of this project is to evaluate the performance of all the recyclables in Taiwan and to examine the impact of resources on the product producers and recyclers behaviors. In this project, we present a mathematical model to analyze the optimal resources level to encourage the product producer to redesign the packaging for the achievement of a more environmental friendly pattern.

In the past one year, an article is completed and submitted to an international journal. More papers can be completed in the coming year. The implementation of this project also yields some additional benefits including the training of research methods on students.

Keywords: extended producer responsibility, recycling performance, recycling fee, resource tax.

目錄

一、 前言

近年來，由於知識與科技的高度發展，造成經濟發展與進步，民眾的環保意識與權 利意識也因而提高，對於自身環境也更顯關心，對於高度敏感性設施，國內所產生的都市垃圾，最主要的處理方法仍然是焚化法，其次才是掩埋法。這兩種方法，多多少少都會產生部分副作用。因此，諸如焚化爐、衛生掩埋場、污水處理場等等的興建，往往引起民眾極大的抗爭。回收行為雖然可以減少最終垃圾處理量，但是，回收處理可以說是事後的補償，亦即環境經濟學上所謂管末處理。由於資源回收的外部利益，在現實生活往往被忽視，在回收政策上，也沒有將之納入政策體系中。垃圾處理的最後端，也未反應這些現象。現行的政策或實際上的垃圾管理運作，並沒有提供任何誘因鼓勵廠商改善產品包裝，以減少垃圾處理 (Nahman and Godfrey, 2008)。如果能從源頭做起，採用預防性措施，減少資源垃圾的產生，當有利於整體環境及未來永續發展目標的實現。

一般認為廠商延伸性責任(extended producer responsibility, EPR) 可以說是斧底抽薪之計，是一種有效減少垃圾產生的預防政策，從源頭做起，要求廠商在設計產品時，必須考慮商品在使用過後所引起的環境衝擊，負起環境責任。其活動精神在於要求廠商對所生產的產品，在消費者消費後，能夠負起環保責任，對於產生之垃圾（報廢品）要負責回收與處理，或是負擔回收與處理費用，以減少對環境衝擊，並進而引導廠商改善產品設計，創新產品預防環境衝擊。因此，一般來說EPR 的特點包含：(1)減少資源浪費的責任，主要由生產廠商負責，要求生產廠商改善製程或產品設計，以減少消費後所產生的衝擊，(2) 產品廠商責任延伸到消費後的階段，廠商不再只考慮生產過程所產生的環境衝擊，對於消費後的衝擊，也必須負擔關鍵性的責任。(3)廠商責任的履行，可以利用金錢誘因，或是政府規範，前者要求廠商自己出力，或出錢透過第三者，為自己所生產

的產品的消費性污染進行回收，後者則是政府制訂實施要點 ，要求特定的收回和再循環率。

環保署在1998 年，成立資源回收管理基金管理委員會(Recycling Fund Management Board, RFMB)，主要業務為辦理應回收廢棄物之回收清除處理費收支事宜、回收處理業輔導管理、建立稽核認證制度及補助地方政府執行資源回收宣導等業務，其下並設有費率審議委員會、稽核認證團體監督委員會、技術諮詢委員會”。用來推動資源回收計畫，並以EPR 的精神，生廠廠商在銷售商品時，要繳交一定金額之回收費給RFMB。環保署透過所制訂四合一政策，要求製造商、進口商繳交一定之回收費，作為回收基金，用以獎勵垃圾收集與資源回收，或用來監督受補貼之收集廠或回收場，瞭解收集與回收是否符合標準，回收數量是否達到要求。部分法定回收品之認證稽核量，除了電子電器物品維持成長趨勢外，其餘物品，到2006-2008 達到最高點後，幾乎呈現震動趨勢。例如在2008年回收量達到2,780,000 台至後，一度下降，然後回升到2011 年的3,869,000 台，然後再度下降。機動車輛的回收量則從1998 年的187,000 輛，成長到2006 年的578,000 輛，之後，就維持下降趨勢。輪胎的回收量則在2000 年之後，維持在110,000 公噸左右。

某些資源垃圾例如鐵罐、鋁罐等回收後之二手料價格高，因此，間接鼓勵回收商進行回收。另外，有些資源垃圾含熱量高例如塑膠袋，即使不回收，直接焚化處理，對環境也不見得是壞事。但是，有些資源垃圾因為回收成本過高或回收過程會產生污染，或回收利潤並不高，例如廚餘，電池，保利龍等，回收商缺乏動力主動回收，只能依賴政府進行回收。從環保署公告之必須回收之資源垃圾的回收率比較，發現電池，保利龍的回收率並不高。

因此，生產者必須負責一定比率之回收責任， EPR 主要的工具為要求廠商在廠品報廢之後負責回收，廠商可以自行投資設備，自己進行回收業務，但也可以與同業合作，委託回收業者進行回收。但是，此種集體的回收系統可能會產生負面效果，部分廠商可能不會進行生態化設計。因此，政府可以依照產品的包裝材料重量，課資源稅。許多廠商，考慮消費者消費習慣，過度包裝，在使用過後，產生過多垃圾，為了減少資源使用，政府應課以資源稅，以降低或減少過度包裝現象。基本上，產品包裝主要考慮美觀之外，也考慮運輸過程中，減少搬運造成碎裂。

考慮國內現形實施EPR 的狀況，本計畫擬針對產品鍊上的產品廠商、消費者、資源回收廠商檢視其對EPR 實施的反應。因此，本計畫首先審視國內的資源回收績效，另外，國內在推行EPR時，其目標往往在鼓勵廠商引進回收技術，使用再生材料，忽略從源頭減量做起。因此，本計畫亦檢視廠商在推行EPR時，對於包裝設計的考量以及減量設計的態度。

本計畫審視國內保裝材料的回收情形，包含塑膠袋、鋁罐、保特瓶、玻璃瓶等。材料再生產業的發展，並檢視 EPR 對包裝材料業的創新的影響。哪些因素影響廢包裝材料的回收與再生？ 資源垃圾回收是否尚有進步空間？檢視目前回收績效是否到達極限？影響垃圾回收的因素為何？如何改善現行回收制度的缺失？檢視現行回收制度的缺失，並提出一套以生產者負責回收的新制度，透過數學模型的推倒，並以實際數字驗證，以估計未來 20 年臺灣的資源回收量與回收績效。本計畫建議以生產者負責回收的新制度，主要考量透過垃圾（廢棄物）處理稅的徵收，可以鼓勵廠商研發新製程，或改善產品設計，以減少包材或天然資源的依賴， 另一方面，又可鼓勵產商設計適當的包裝水準，減少過度包裝，以

降低生產成本。

研究方法

本計畫包含兩種研究目的，亦即：資源垃圾的回收績效分析和資源稅的制訂。因此，針對不同的研究目的，分別採用不同的研究方法，前者運用panel data與統計迴歸模式、分析國內資源垃圾的回收績效。後者則建構數學模式，以政府立場，制訂最適回收費費率，並進行敏感度分析，檢討費率的高低對產品廠商的新料選用的比率與資源垃圾產生量的影響，以及探討費率高低對回收廠回收量的影響。

資源垃圾的主要組成包含廢紙、廢金屬、廢玻璃製品、廢塑膠和橡膠、廢家電、廢資訊產品、廢電子設備、廢電池等等。以 2012 年為例，廢紙回收量為 1,717,287 公噸，佔所有資垃圾中的 54.21%，領先其他資源垃圾的回收。本年度計畫將以環保署所統計資料為主，分析各種資源垃圾的回升績效。

環保署在統計各種垃圾的回收績效時往往以回收率作基準，然而，採用回收率作為評估回收績效有其盲點與限制，環保署所定義的回收率是以資源垃圾回收量除以總垃圾收集量。並未考慮原始垃圾產生時的垃圾成分，換句話說，該資源垃圾在原始垃圾產生時的含量並未考慮進去。假如該資源垃圾在原始垃圾產生時的含量已經很低，則回收率無論績效多好，回收率數字絕對是低的。因此，本計畫建議採用減量率作為評估依據。亦即，該資源垃圾回收量（或回收率）除以該資源垃圾在原始垃圾產生時的數量（或潛在回收率），作為回收績效的依據。因此，本計畫利用The Bass model 來找出每一種資源垃圾的潛在回收率，然後以現行回收率與潛在回收率比較，作為回收績效指標用來衡量回收績效。

The Bass model 已經用來探討新興產品、吉數研發、或是新觀念的流通（例如. Islam,et al., 2002; Dekimpe, et al., 1998; Fok and Franses, 2007). 其數學式如下所示：

$$\frac{dn(t)}{dt} = p \ [M - n(t)] \ + \ q \frac{n(t)}{M}[M - n(t)] \qquad (1)$$

式子中，$n(t)$ 代表在t 時點的累積接受者，p 和 q 則是外在和內在影響係數，M 是接受者的極限數量。外在影響可能透過廣告或文宣等，內在影響則是口耳相傳。在資源垃圾回收觀念的擴散方面，政府可以扮演推廣角色，Janssen and Jager（2002）就說明政府是扮演加速綠色產品擴散的角色；式子(1)用來描述資源垃圾回收情形時，$n(t)$ 則是代表 t 時點的回收率，M 則代表潛在回收率。式子(1)改成差分方程式（difference equation），得

$$x_t = \alpha_0 + \alpha_1 n_{t-1} + \alpha_2 n_{t-1}^2 + \varepsilon_t \qquad (2)$$

式子(2) 中，x_t 代表資源垃圾的回收率變化量，ε_t 則是誤差項。比較式子(1)和式子(2)可得：

$$\alpha_0 = pM \qquad (3)$$

$$\alpha_1 = q - p \qquad (4)$$

$$\alpha_2 = \frac{-q}{M} \qquad (5)$$

因此，從式子(2)-(5) 可計算出潛在回收率的估計值$\hat{M}$ 。許多學者運用the Bass model 來預測 p， q 和 M值 (e.g. Van den Bulte and Stremersch, 2004; Venkatesan, et al. 2004; and Van den Bulte and Lilien, 1997)。透過數學運算，解(3)-(5)的連力方程式，可得

$$\hat{p} = \frac{-\hat{\alpha}_1 + \sqrt{\hat{\alpha}_1^2 - 4\hat{\alpha}_0\hat{\alpha}_2}}{2} \qquad (6)$$

$$\hat{q} = \frac{\hat{\alpha}_1 + \sqrt{\hat{\alpha}_1^2 - 4\hat{\alpha}_0\hat{\alpha}_2}}{2} \qquad (7)$$

$$\hat{M} = \frac{-\hat{\alpha}_1 - \sqrt{\hat{\alpha}_1^2 - 4\hat{\alpha}_0\hat{\alpha}_2}}{2\hat{\alpha}_2} \quad (8)$$

每一種（i）資源垃圾的回收績效為

$$\eta_i = \frac{n_i(t)}{\hat{M}_i} \quad (9)$$

表一顯示台灣在1998-2012 垃圾產生量和回收量，顯示垃圾產生量逞現減少趨勢，且回收量也逞現增加趨勢，顯示整體垃圾管理的績效是正面的。回收量由1998年的111,753 噸增加到2012的4,091,180噸，年成長率為24.98%。在2012年，約54.76％ 的垃圾透過回收系統，變成回收料。環保署將資源垃圾分成三類：可回收資源垃圾、廚餘、大型垃圾。可回收資源垃圾佔總回收的77.42%，為資源回收的最主要功臣。主要成分為廢紙、廢鐵罐、廢玻璃罐、廢塑膠、廢橡膠、家電產品、廢輪胎、廢電池、等等。其中，廢紙量佔最大宗，有 1,717,287 噸，佔總資源垃圾的54.21% ，其次，廢金屬 有 707,403 噸 (22.33%),廢塑膠、廢橡膠有320,763 tonnes (10.13%), 廢玻璃有 242,068 tonnes (7.64%).

1980-2000年各類資源垃圾回收率顯示於圖一（Fig. 1），從圖一可以看出，各類資源垃圾的回收率都維持成長趨勢。 資源垃圾回收率從1998年的1.25%增加到2012年的42.40%，廚餘則由年的2.27% 增加到2012年的11.17%，大型垃圾則從2005年的0.38%增加到2012年的1.19%。

Table 1. Amount of MSW collected, disposed, and recycled unit: tonnes

	MSW generated	MSW disposed	Waste recycled			
			Sub-total	Recyclables	Food waste	Bulk waste
1998	8,992,240	8,880,487	111,753	111,753	n.a.	n.a.
1999	8,715,575	8,565,699	149,876	149,876	n.a.	n.a.
2000	8,353,368	7,875,511	477,856	477,856	n.a.	n.a.
2001	7,839,173	7,254,841	584,333	584,333	n.a.	n.a.
2002	7,601,958	6,723,639	878,319	878,319	n.a.	n.a.
2003	7,355,335	6,139,050	1,216,285	1,048,981	167,304	n.a.

2004	7,554,870	5,862,890	1,691,980	1,392,715	299,265	n.a.
2005	7,775,064	5,525,253	2,249,811	1,756,035	464,201	29,575
2006	7,738,531	5,032,672	2,705,859	2,107,037	570,176	28,646
2007	7,975,686	4,873,237	3,102,450	2,408,429	662,791	31,230
2008	7,607,798	4,374,154	3,233,645	2,497,985	691,194	44,466
2009	7,729,231	4,223,484	3,505,748	2,718,803	721,472	65,473
2010	7,870,665	4,072,603	3,798,062	2,948,681	769,164	80,217
2011	7,485,229	3,610,848	3,874,380	2,982,855	811,199	80,326
2012	7,470,569	3,379,390	4,091,180	3,167,656	834,541	88,983

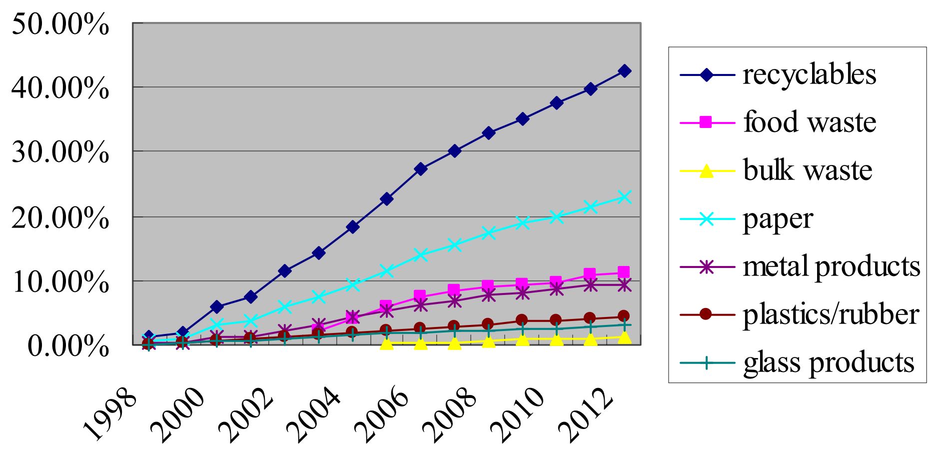

Figure 1. The trend of recycling rate among waste fractions

另外，針對資源稅的制訂，本計畫則考慮產品廠商與回收商可以說是一種供應鏈關係，產品廠商所生產的產品在報廢後，由回收商負責收回處理。因此，回收商必須對原料（即報廢品）、生產（回收）、存、配送、購買等環節有一定的管理，使能達成整合性（integrated）的運作方式，以提高生產作業效率。許多學者利用 LCA（life cycle assessment)、線性規劃方法、數學最佳化模式等企圖預測報廢品的回收率，例如 Kahhat et al. (2008), Nnorom and Osibanjo (2008), Park et al. (2006), Ruhrberg (2006)等等。一般來說，報廢品（例如電腦、汽車）的回收率，受到許多因素的影響，包括產品設計，產品所用材質的特性，組裝的精細等等。

EPR 需要製造商、進口商共同合作，提供基金，獎勵消費後之報廢品回收工作。 一般 EPR 的實踐有兩種方案：廠商自行回收所製造產品的報廢品，並在企業內部設立相關單位，此種方式往往增加財務上的投資，會導致成本上的增加(Mayers, 2007)。第二種方式則是回收商負責回收，此種方式往往以商品數量為單位，在商品銷售時，課取一定的規費，然後，再委託專業的回收者，負責回收。回收廠商必須建立硬體設施，制訂管理章程，針對會員所生產之報廢產品，進行回收與處理。故此種方式又稱為集體垃圾管理系統（collective waste management systems，Castell et al., 2004; Mayers, 2007)。此種方式，容易導致部分廠商不願改善其產品設計，降低材料使用量。因此，學者主張應針對個別廠商之責任，訂立相關之管理系統，以敦促廠商改善產品之生態設計，減少垃圾產生量 (Lifset and Lindhqvist, 2008; Lindhqvist and Lifset, 2003)。

本計畫先利用數學模型，探討最佳回收費或資源稅的制訂。由於回收費是依照產品廠商所生產之產品數量課以一定的回收費，如上所述，廠商會有轉嫁行為，不會改善商品設計，減少資源使用。因此，為了鼓勵廠商進行生態化設計等投資，要求個別廠商負責的系統有其必要，雖然此種系統在實施上，可能會有較高的成本(Lifset and Lindhqvist, 2008; Lindhqvist and Lifset, 2003)。因此，實務上，都是由政府出面，透過政策制訂，要 求廠商在產品銷售前支付一定的垃圾處理費，以負擔產品報廢之後所需的回收處理成本(Clift and France, 2006)。因此，本計畫以廠商所使用的新料使用量，作為課取回收費之依據。本計畫假設產品廠商在設計其產品時，包裝會增加產品吸引力以及銷售量，因此，本計畫假設需求函數為雙邊取對數 (Log-linear) 之函數型態 (如 Cobb-Douglas 需求函數)，需求主要受到產品價格及包裝水準的影響，其需求函數可表示為：

$$q = f(P, w) = A^{-1} p^{a} w^{b} \qquad (9)$$

式(9) 中，A^{-1}是常數，a 是產品的需求彈性，且$a<0$，b 是包裝水準之需求彈性，且$b>0$。由式(9) 得

$$P = A\ q^{\alpha}\ w^{\beta} \tag{10}$$

式(2)中，$\alpha = \dfrac{1}{a}$，$\beta = \dfrac{b}{a}$。

廠商是利潤追求者，因此，廠商在面臨式(10)需求函數時，當決定適當的生產水準q 與包裝水準w，亦即廠商所面臨的問題如下所示：

$$\max_{q,w}\ pq - c_1\ q - c_2\ w - tw \qquad \text{(P1)}$$

問題(P1) 中，c_1 是產品之單位生產成本，c_2是產品包裝之單位生產成本，t 是所課之垃圾處理費。將式(10)需求函數代入問題(P1) 中，求取利潤極大之一階與二階條件下，即可求解，最佳產量q^*、包材水準w^*。

另外，政策設計者主要以社會福利極大為目標函數，政府考慮利用廠商的反應函數(亦即問題(P1)所產生之最佳解)，制訂適當的稅率，以追求社會福利最大，因此，政策設計者所面臨的問題表示如下：

$$\max_{t}\ \int_{o}^{q} A\left(\frac{q}{w^{\beta}}\right)^{\frac{1}{\alpha}} dq\ -\ c_1 q - c_2 w - \tau w \qquad \text{(P2)}$$

問題(P2) 中，τ 是垃圾單位處理費用。在滿足社會福利極大之一階與二階條件下，經過計算可以解所得之最佳稅率t^*。

研究結果與討論

本計畫執行至今，總共完成1篇論文，部分尚在進行中，所完成的論文已投稿國際期刊，詳細內如如附錄。所完成論文的主要研究目的在瞭解國內資源垃圾回收的情形，以及影響回收率的因素。歷年來，臺灣整體的資源垃圾回收績效，是否有進步？進步的因素為何？如何改善缺失？環保署在統計各種垃圾的回收績效時往往以回收率作基準，然而，採用回收率作為評估回收績效有其盲點與限制，環保署所定義的回收率是以資源垃圾回收量除以總垃圾收集量。並未考慮原始垃圾產生時的垃圾成分，換句話說，該資源垃圾在原始垃圾產生時的含量並未

考慮進去。假如該資源垃圾在原始垃圾產生時的含量已經很低，則回收績效無論多好，回收率也可能是低的。因此，本計畫收先提出一新的指標，用來衡量回收績效，用以和目前環保署所使用的回收率作比較。

Marques et al. (2012)以葡萄牙為例，利用非參數模型，檢視以營利為目的之回收商的回收績效，其研究結果發現缺乏獎勵誘因是回收缺乏績效的主要原因。Chen (2010) 分析環境管理制度的管理績效，Chen and Chen (2012) 則是分析焚化爐的經營績效，並比較公民營的效率差異。鄭信德(2011)則是分析並比較各縣市的資源回收管理績效，以資源垃圾回收量作產出，以人力、機具、投入經費作為投入，用DEA 模式，分析源回收管理績效。這些研究所探討的，主要針對垃圾管理機構提出績效分析，相對的，本計畫所完成的論文，則是探討各種資源垃圾的回收績效，亦即探討資源垃圾回收量與資源垃圾產生量的比率，用來探討比較產業所生產的資源垃圾（報廢品）的回收績效。

所發表論文之研究結果，請參閱附件一。

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附件

The diffusion effect of MSW recycling

Abstract

The purpose of this paper is to compare the recycling performance for some waste fractions selected including: food waste, bulk waste, paper, metal products, plastics/rubber and glass products, and then to develop some directions for the future improvements. The priority of each waste fraction for recycling is also analyzed by using an importance-performance analysis. Traditionally, the recycling rate that is calculated by the ratio of waste recycled to waste collected is used as an indicator to measure recycling performance. Due to a large variation among waste fractions in MSW, the recycling rate cannot reflect the actual recycling performance. The ceiling of recycling rate for each waste fraction estimated from the diffusion models is incorporated into a model to calculate recycling performance. The results show that (1) the diffusion effect exists significantly for the recycling of most recyclables, but no evidence is found to support the diffusion effect for the recycling of food waste and bulk waste; (2) the recycling performance of waste metal products ranks the top, ahead of waste paper, waste glass and other waste fractions; (3) furthermore, an importance–performance analysis (IPA) is employed to analyze the priority of recycling programs and thus this paper suggests that the recycling of food waste should be seen as the most priority item to recycle.

Keywords: diffusion effect; municipal solid waste; recycling performance; recovery

1. Introduction

Due to resources scarcity and environmental concerns, the recycling of municipal solid waste (MSW) is believed as an effective tool for waste management to sustain development and becomes more and more important in reducing resource scarcity in a growing society. Waste recycling in general provides some benefits: resource recovery, the saving of MSW disposal and transportation costs, the assurance of environmental cleaning and the extension of the life spans of MSW disposal facilities. And thus, an improvement in MSW recycling performance should be focused in addition to the efficiency enhancement of MSW management relating to MSW disposal facilities.

The principles of 'reduce, recycle, reuse' has been accepted as a top guide for the management of municipal solid waste (MSW) in Taiwan. The MSW recycling has increased 34 folds over the period of 1998-2012, increasing from 111,753 tonnes in 1998 to 3,798,062 tonnes in 2012. And thus, the first purpose of this paper is to analyze the recycling performance of some waste fractions selected. Traditionally, the recycling rate is used as an indicator to measure recycling performance. Recycling rate is however calculated by the ratio of waste recycled to waste collected. Such a measure seems not possible to reflect the actual performance of recycling as the amount of each waste fraction in MSW varies greatly. And thus, a new formula is developed in this paper to calculate recycling performance by incorporating the ceiling of recycling rates that is estimated and obtained by the diffusion model presented in this article. This paper also evaluate the relative recycling performance among some waste fractions and then to develop some directions for the future improvements. The priority of each waste fraction for recycling is also analyzed by using an importance-performance analysis.

Most articles examine the impacts of household or citizen behaviors on MSW recycling (Evison and Read, 2001; Thomas, 2001), or compare the education programs to increase public participation in recycling program (Evison and Read, 2001; Mcdonald and Oates, 2003; Timlett and Williams, 2008). Many researchers emphasize that the improvement of recycling rate depends on environmental education to encourage the public to participate in the recycling programs. On the other hand, some researchers focus on the economic and social factors to affect the success of recycling programs (Martin et al., 2006; Mcdonald and Oates, 2003; Perrin and Barton, 2001; Tonglet et al., 2004).

Very few papers highlight the diffusion effect in affecting MSW recycling performance. Chen and Chang (2010) examine the interaction of diffusion effects and learning effects for MSW recycling by using the aggregate data and their resulting conclusions suggest that (1) both diffusion effects and learning effects have significantly impacts on MSW recycling and (2) environmental policy plays an important role in affecting MSW recycling. In general, diffusion models have been widely employed to forecast the spread of an innovation over time (Islam and Meade, 2000; Sohn and Ahn, 2003, Kemp and Volpi, 2008). As Kemp (1997, p.9) defines environmental technology as "each technique, process or product which conserves or restores environmental qualities" and classify it into six categories including (i) pollution control technologies, (ii) waste management, (iii) clean technology, (iv) recycling: waste minimization through the re-use of materials recovered from waste streams, (v) clean products, and (vi) clean-up technology, this paper suggest that MSW recycling can be seen as an environmental technology. And thus, the diffusion of MSW recycling is modeled as a diffusion process of environmental technology.

2. Research methods

Diffusion is defined as "the process in which an innovation is communicated through certain channels over time among the members of a social system. It is a special type of communication, in that the messages are concerned with new ideas" (Rogers, 2003, p. 5). The diffusion process, in practice, reflects a communication process about the spread of information and the timing of individual adoptions (Rogers, 2003; Gatignon and Robertson, 1991). Redomnd (2004) argues that "In a broader sense, however, the process of diffusion involves the spread of newness through society, which entails broad-scale changes in both behaviors and perceptions" (p. 1295).

Many researchers focus on the communication technologies and examine the diffusion across countries (Bohlin, et al. 2010; Kumar & Krishnan, 2002;), the substitution of new generation mobile phone for fixed networks (Michalakelis, et al. 2010) or the difference in diffusion patterns across countries that express diversity in social, cultural and economic characteristics of countries (see e.g. Stremersch & Tellis, 2004; Talukdar, Sudhir & Ainslie, 2002; Redmond, 2004). Bohlin et al. (2010) examine the diffusion of new generation products of mobile telecommunication technologies. They find that the factors including per capita income, urbanization and Internet/broadband penetration and regulation have positively influence diffusion across all generations of mobile telecommunication products. Michalakelis, et al. (2010) focus on telecommunication products and services, and examine the generational substitution effects due to the emergence of new generation products stemming from rapid technological changes. Kogut and Macpherson (2011) see economic policies as innovations and examine the impacts of three types of economic policy innovations including privatization, central bank independence, and pension reform on social welfare. Their results find that the diffusion of economic policy innovations depends on the mobility of economists. Redmond (2004) discusses the factors involving social comparison, the network structure of interpersonal communications, and prestige seeking and their impacts on the speed of technology diffusion. He finds that social networks may encourage the adoption of new technologies, but some networks also may inhibit or discourage such adoptions. Peres et al. (2010) employs diffusion models to examine the diffusion process of innovative products and services across markets and brands.

The Bass model has been widely employed for empirical studies to capture a wide variety of diffusion patterns (Kemp, 1997; Geroski, 2000). Many researchers have applied the Bass model to test or to forecast sales of a new product in various fields (e.g. Islam, et al., (2002) and Dekimpe, et al., (1998) for telecommunication; Fok and Franses (2007) for scientific researches). In general, the Bass model is expressed by a differential equation as:

$$\frac{dn(t)}{dt} = p \quad [M - n(t)] \quad + \quad q\,\frac{n(t)}{M}[M - n(t)] \tag{1}$$

where $n(t)$ is the accumulated adopters at time t, p and q are coefficients of external and internal influence respectively, and M is the ceiling of adopters. The Bass model assumes that the potential adoption is influenced by two types of communication channels: external influence of mass mediated process and internal influence through word of mouth that interacts between adopters and non-adopters in a social group. The first term explains the factor for the adoption due to mass media as it depends only on the number of non-adopters in the system. The second term describes the adoption due to word of mouth interaction. And thus, Eq. (1) is employed to examine the diffusion effect of MSW recycling among various recyclables, where $n(t)$ is the recycling rate at time t, and M denotes the ceiling (maximum) of recycling rate. By rearranging Eq. (1) and converting it into a difference equation, we obtain

$$x_t = \alpha_0 + \alpha_1 n_{t-1} + \alpha_2 n_{t-1}^2 + \varepsilon_t \tag{2}$$

where x_t denotes the difference of recycling rate for each waste fraction of recyclables, and ε_t is the error term. Comparing Eq. (2) with Eq. (1), we obtain

$$\alpha_0 = p M \tag{3}$$

$$\alpha_1 = q - p \tag{4}$$

$$\alpha_2 = \frac{-q}{M} \tag{5}$$

Many researchers have employed the Bass model to estimate the parameters p, q and M (e.g. Van den Bulte and Stremersch, 2004; Venkatesan, et al. 2004; and Van den Bulte and Lilien, 1997). Following to these studies, the estimated coefficient for external force $\hat{p}$, internal force $\hat{q}$, and the ceiling of recycling rate $\hat{M}$ is obtained by solving the simultaneous equations of Eq. (3)-(5), and listed in Eq. (6)-(8).

$$\hat{p} = \frac{-\hat{\alpha}_1 + \sqrt{\hat{\alpha}_1^2 - 4\hat{\alpha}_0\hat{\alpha}_2}}{2} \tag{6}$$

$$\hat{q} = \frac{\hat{\alpha}_1 + \sqrt{\hat{\alpha}_1^2 - 4\hat{\alpha}_0\hat{\alpha}_2}}{2} \tag{7}$$

$$\hat{M} = \frac{-\hat{\alpha}_1 - \sqrt{\hat{\alpha}_1^2 - 4\hat{\alpha}_0\hat{\alpha}_2}}{2\hat{\alpha}_2} \tag{8}$$

On the other hand, the performance of recycling η_i for ith waste fraction is estimated by:

$$\eta_i = \frac{n_i(t)}{\hat{M}_i} \tag{9}$$

2.2 data

Table 1 shows the amount of MSW generated and recycled over the period of 1998-2012. The MSW generated kept a decreasing trend but the waste recycled grew by 24.98% annually, increasing from 111,753 tonnes in 1998 to 4,091,180 tonnes in 2012. In 2012, about 54.76 % of MSW generated was recycled to produce secondary materials. Taiwan EPA classifies waste recycled into three main streams: recyclables, food waste and bulk waste. In 2012, total waste recycled amounted to 4,091,180 tonnes, accounting for 54.76% of MSW generated. Among the three streams, recyclables ranked the top, contributing to 77.42% of total waste recycled. In consideration of historical trends, Table 1 indicates that recyclables increased from 111,753 tonnes in 1998 to 3,167,656 tonnes in 2012, food waste increased from 167,304 tonnes in 2003 to 834,541 tonnes in 2012 and bulk waste increased from 29,575 tonnes in 2005 to 88,983 tonnes in 2012.

Insert Table 1 about here

The major fractions of recyclables include waste paper, waste metal products, waste glass products, waste plastics/rubbers and a small portion of recyclables consists of textile products, home electrical appliances, batteries, information and communication products and others. In 2012, waste paper recycled reached to 1,717,287 tonnes, accounting for 54.21% of recyclables, ahead of waste metal products 707,403 tonnes (22.33%), waste plastics/rubber 320,763 tonnes (10.13%), and waste glass products 242068 tonnes (7.64%). The sum of these four waste fractions accounts for 94,31% of total recyclables.

In overall, this paper selects six categories of waste fractions for analyzed, including: food waste, bulk waste, paper, metal products, plastics/rubber and glass products. Since the amount of MSW generated reduces over time, we employ the recycling rate rather than the recycling amount to measure diffusion effects. The recycling rate for the waste fraction selected over the period 1980-2000 is illustrated in Fig. 1, in which we find that recycling rate for all these waste fractions have kept an increasing trend over time. The recycling rate of recyclables increased from 1.25% in 1998 to 42..40% in 2012 and that of food waste increased from 2.27% in 2003 to 11.17% in 2012. The bulk waste increased from 0.38% in 2005 to 1.19% in 2012.

In 2012, about 0.42 tonnes of recyclables containing various recyclable resources including paper, metal products, glass, plastics and rubbers is collected and recycled in each tonne of MSW. Among the various waste fractions of recyclables, the recycling rate of waste paper reached to 22.99% in 2012, ranking the top, followed by metal products with recycling rate of 9.47%, plastics/rubbers of 4.29% and glass of 3.24%. The recycling rate for the remaining recyclables including textile products, home electrical appliances, batteries, information and communication products, agricultural chemical containers and others is only 2.41% in 2012.

Insert Figure 1 about here

3. Research results

The test results of Eq.(2) for recyclables, food waste, bulk waste, paper, metal products, plastics/rubber, and glass products are listed in Table 2. The results show that the recycling of recyclables, waste paper and waste metal products behaves as logistic pattern over time as the coefficient of square recycling rate is significantly negative. And thus we conclude that diffusion effects exist for the recycling of aggregated recyclables, the fraction of waste paper and waste metal products. On the other hand, no evidence is found to support that diffusion effects exist for the recycling of food waste, bulk waste, waste glass and waste plastics/rubber.

The existence of diffusion effects for waste metal products and waste paper may attribute to the establishment of recycling system consisting of collecting, sorting, recovery and the market of secondary materials. Rogers (2003) suggests that the compatibility with social values, beliefs and past experiences may play an important role in affecting the adoption rate. The effectiveness of MSW recycling in general depends on household's environmental awareness and behaviors with sufficient knowledge to keep materials separate (McDonald and Ball, 1998; Perrin and Barton, 2001). In fact, some researchers has emphasized that knowledge in recycling is very important for successful MSW management (Perrin and Barton, 2001). Currently, MSW sorting by households at home has been successfully performed in Taiwan and reached to high efficiency (Chen, 2010). The communications and information flow are sufficient between households and governmental administrative units to adopt new knowledge or regulation. Taiwan's household's participation in MSW recycling is recognized and believed to play a vital role in affecting recycling performance.

Insert Table 2 about here

The estimates of $\hat{p}$, $\hat{q}$, and $\hat{M}$ are shown in Table 3, in which the rate of diffusion through external force for waste paper recycling is smaller than waste metal products, but the rate of diffusion through internal force is almost the same between the two waste fractions. The variation of diffusion rate may be accounted for by the market structure and size of secondary materials. Currently, the regenerated steel and irons in Taiwan can satisfy about 60% of local market demand and thus about of 40% of waste metal products should be imported. Starting from 2006, four waste metal re-processing plants were subsidized to crush the waste car and to regenerate metal materials. About 85% of the shredded steel and irons are consumed by electric arc furnace plants (Institute of Environment and Resources, 2014).

Insert Table 3 about here

Based on Eq. (9), recycling performance is calculated and the trend of recycling performance for aggregate recyclables, waste paper and waste metal products are illustrated in Figure 2. The recycling performance of each waste fraction seems to have kept a rising trend over the period of 1998-2012 for these three waste fractions. The recycling of waste metal products has started to perform better than waste paper since 2002 and ranked the top in 2012. By 2012, recycling performance for recyclables, waste paper, and waste metal products has reached to 89.09%, 85.27%, and 96.17%, respectively. The comparison among these three waste fractions shows that the recycling of metal products has almost reached to its potential recycling rate.

Insert Figure 2 about here

4. Importance-Performance analysis

The importance–performance analysis (IPA) has been widely used to analyze customer satisfaction, containing two dimensions: importance of quality attributes and attributes performance. In this paper, we employ it to form a priority program for waste recycling. The importance of waste recycling for each waste fraction is depicted along the x-axis and recycling performance along the y-axis in this paper. Recycling performance is measured in terms of the relative attainment rate that is calculated according to Eq. (9) for recyclables, waste metal products and waste paper. In contrast, food waste, waste glass and waste plastics/rubber are not found to have significant diffusion effects. Hence, the content of these three waste fractions in MSW before sorting is used as the ceiling of recycling rate respectively. Currently, bulk waste is collected and transferred to the re-manufacturing plant, owned and operated by the government for once or twice only in a year. The content of bulk waste in MSW is not available and thus bulk waste is excluded for importance-performance analysis.

On the other hand, the attribute importance is measured by the relative benefit of waste recycling (sorting, collecting and material recovery). Since all the incinerators have been equipped with energy recovery systems in Taiwan, some waste fractions such as paper, plastics films, etc. can be seen as compensatory fuels for power generation. In this case, the calorific value of each waste fraction, contributing to outputs of electricity production, is used as the measure of relative importance. The data of caloric values for food waste, paper, metal products, glass, and plastics/rubber shown in Table 5 in Chen and Chen (2013) are employed. As the caloric values of these waste fractions vary greatly, the relative importance (*RI*) is developed in terms of

$$RI_i = \frac{(\mu - h_i)}{\sigma} \qquad (10)$$

where h_i is the caloric value of ith waste fraction, μ is the average of caloric values for all waste fractions selected, and σ is the standard error.

The relative performance η_i and importance RI_i for these selected waste fractions are shown in Figure 3, that dividing the matrix into four quadrants. Waste metal products and glass fall in Quadrant I with recycling performance of 0.9617 and 0.8504 respectively. As zero caloric values for these two waste fractions, the relative importance is 1.3961 calculated. This means that the recycling of waste metal products and glass should keep going to maintain the sustainable competitive advantage.

Food waste falls in Quadrant IV, representing high scores 0.8767 of recycling importance but low scores 0.3918 of recycling performance. In 2012, the recycling rate for food waste was 11.17% only but MSW for final disposal still contained 38.33% food waste. The results suggest that MSW management authorities should pay more attention to the recycling of food waste and see it as the most priority item to recycle. In fact, food waste should be avoided to enter incinerator due to its negative impacts on the both the incinerators and the environment (Chen and Chen, 2013). Chen and Chen (2013) compares material recycling and energy recycling for some waste fractions and suggests that material recovery for food waste is more appropriate due to its low caloric value of 4.18 MJ/kg. The results of IPA implies that recycling of food waste requires immediate attention and thus MSW management should see it as a priority task by providing new mechanism to speed up diffusion effects and encourage recycling performance.

On the other side, Waste paper and plastics/rubber fall in Quadrant II and Quadrant III, implying less importance to recycle. As Quadrant III represents excessive inputs of resources for recycling, and thus the resource for recycling waste paper should be deployed elsewhere. Among the waste recycled, recycling rate of waste paper was 22.99% in 2012, ranked the top, higher than food waste (11.17%), metal products (9.47%), plastics/rubber (4.29%) and glass products (3.24%). Chen and Chen (2013) suggest that waste paper may be more appropriate to dispose through energy recovery rather material recovery due to high waste caloric values contained in waste paper. Therefore, management authorities may divert efforts of recycling from waste paper to other waste fractions.

Finally, Quadrant III represents low importance and low performance for material recycling. The waste fraction of plastics/rubber falling in this quadrant has recycling performance of 37.51% and attributes importance of -2.9528 with high caloric value of 35 MJ/kg.

In practice, plastics materials are difficult to be recovered as they are mostly used as packaging materials that are made of composite materials consisting of plastics film, paper. Al foil, or other materials. Plastics packaging materials having high caloric value and seen as a bio-fuel may be more appropriate to recovery energy through incineration process This paper suggest that recycling of waste plastics/rubber can be seen as an low priority item for MSW management.

Insert Figure 3 about here

5. Discussions and conclusions

Analyzing the diffusion effect for each waste fraction of recyclables, this paper concludes that the existence of diffusion effects varies across different waste fractions. Waste metal products and waste paper are found to have significant diffusion effects while the rest are lacking of evidence. Since all waste fractions of recyclables are equally sorted, some other factors except for household participation may explain the difference in the existence of diffusion effects among these waste fractions of recyclables. The other reason to explain the variation of diffusion effects across these waste fractions may attribute to the market demand for secondary materials and the relevant recycling system. In practice, a lot of secondary material market has formed in Taiwan including recyclable waste collectors, recyclable waste distributors, recovery plants, secondary materials dealers, and the buyers for secondary materials. Recovery and/or regeneration of most waste fractions such as waste metal products, waste paper, and waste plastics has been conducted in Taiwan through the integration of collectors, scrap dealers, regeneration (recovery) plants, and other recycling facilities. With the recent investments in the recycling industry, almost all types plastic materials, glass, paper and metals can be recycled at industrial levels in Taiwan. However, the market for other waste fractions is still lacking due to low market demand.

Among these waste fractions, the material recovered from waste papers, waste metal products and waste PET containers has a stable market, and can compete with international market price. Waste paper are collected through the scrap/waste dealers and delivered to material recovery plants to produce paper stock through a series process of sorting, grading, and baling. The paper stock recovered is sold on the market to paper recycling mills or paper products making plants for the manufacture of paper products.

In 2011, Taiwan's market demand for waste metals reached 11.7 million tonnes and still kept rising with an average annual growth rate estimated at 4.97% (U.S. Commercial Service, 2014). Currently, 25 electric furnace steel mills have been established with total capacity of 14.2 million tons. In general, approximately 1.1 metric tons of steel scrap can produce 1 metric ton of crude steel. Due to high dependence on importation of steel scrap, the market demand for waste metals is stable and thus recycling of waste metal products become an economic behavior.

The stream of waste plastics contains a variety of materials such as PET, PP and PE accounting for 89.4% of waste plastics recycled (Institute of Environment and Resources, 2014). The rest of waste plastics sources from the waste electronic appliances. Basically, the quality of regenerated plastics is lower than virgin materials and thus reduces its demand in local market. Currently, about 70% of secondary materials recovered from waste plastics are sold in domestic market and the rest is exported (Institute of Environment and Resources, 2014). Due to difficult recovery for some packaging materials made of plastics and other composite materials, these packaging materials containing plastics are in practice incinerated with general MSW for energy recovery. Theoretically, waste tyres can be re-manufactured or regenerated through thermal cracking to produce rubber. However, the major application of waste tyres collected are used as fuels for co-generation plants or cements plants in Taiwan. Due to the limited application of waste plastics and rubber, the diffusion effect for the recycling of plastics/rubber is not found significant in this study. The lacking of market demands for secondary plastics materials and the adoption of incineration disposal with energy recovery for some plastics may be the key factor to explain the insignificant diffusion effects for the recycling of plastics/rubbers.

Most of waste glass is collected from waste glass containers, accounting for 87.7% of waste glass recycled, and the rest is contributed by other sources including wasted TV CRT, computer monitors, and lightening (Institute of Environment and Resources, 2014). Currently, no market exists for waste glass and thus it reduces the diffusion of waste glass recycling.

The food waste collected is currently delivered to pig farms as pig feed or composting plants for the conversion of food waste into fertilizers in Taiwan. As food waste comes from a variety of sources like households, restaurants, and military organizations, the sanitary quality is very difficult to monitor and control. The pathogens may be contained in the food waste, and relatively high risk of disease infection exists. The infection rate of toxoplasmosis is 48% for the pig farm fed by food waste, higher than 8.3% by formula feed (Lu, 1995). And thus, Council of Agriculture in charge of agriculture development policy opposes to expand the application of pig feed for food waste (Song, 1998). The lacking of diffusion effects for food waste may attribute to the limited applications of food waste and the lacking of competition pressure for the organic fertilizers composted from food waste collected.

The biological composting for food waste has been proved to be a successful method both in technical perspective and economic evaluation, and generally accepted as a rapid and simple process to stabilize and reduce the waste mass. It is also seen as the most natural way of recycling through biological reactions to achieve environmental self-cleaning among the various disposal options (Caputo and Pelagagge, 2002; Slater and Frederickson, 2001). However, the cost of organic fertilizer composted from food waste is still lacking of competitiveness with respect to chemical fertilizers. According to Council of Agriculture (2014), the market share of organic fertilizer is less than 10% of total fertilizer consumption. Considering the high volume of food waste generated, Taiwan EPA started to promote the food waste recycling in 2003. After then, the food waste recycling rate increased from 2.27% in 2003 to 11.17% in 2012 (Taiwan EPA, 2014). Currently, the MSW disposed still contains food waste 38.33% and hence this paper suggests that MSW management authority should focus on the recycling of food waste.

In general, recovery plants aim at maximizing profits and thus may work as a pulling force for sorting and collecting of recyclable wastes. The price competition and quality of secondary materials are critical to affect the demands for the recyclable waste. In fact, waste recycling and recovery of valuable materials will be conducted autonomously if the recycling provides profits or at least a substantial saving on waste disposal costs (Chen, 2005).

The contribution of this paper at least includes three folds: (1) the new formula that incorporates the ceiling of recycling rate to measure recycling performance seems to be more realistic and effective to reflect recycling performance compared to recycling rate; (2) the results of the empirical analysis on the diffusion effect for various waste fractions highlights the role of secondary materials market in affecting the diffusion of MSW recycling; (3) the importance-performance analysis provides a recycling priority program to support the policy making and planning.

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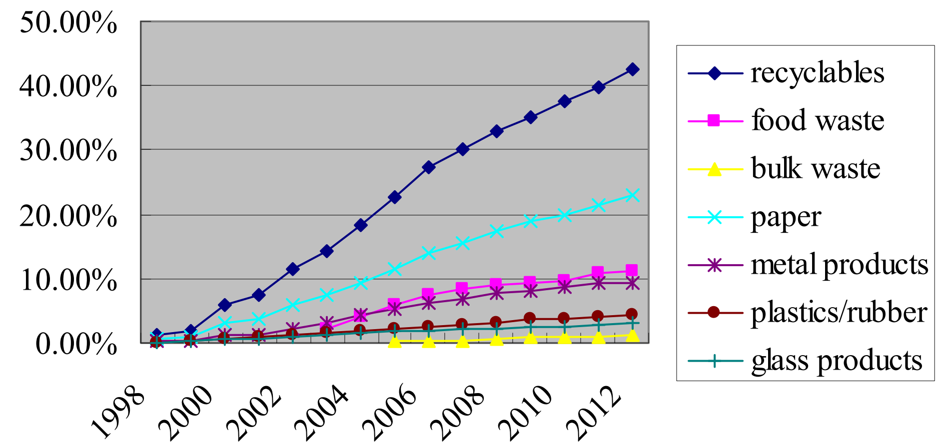

Figure 1. The trend of recycling rate among waste fractions

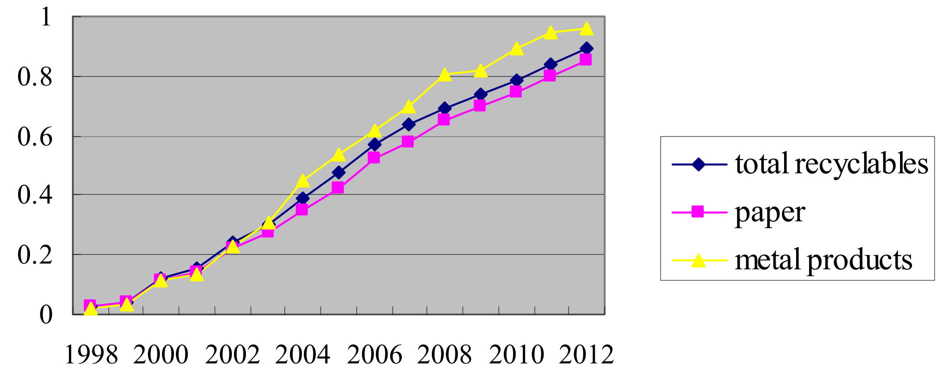

Figure 2. The comparison of recycling performance among total recyclables, waste paper and waste metal products

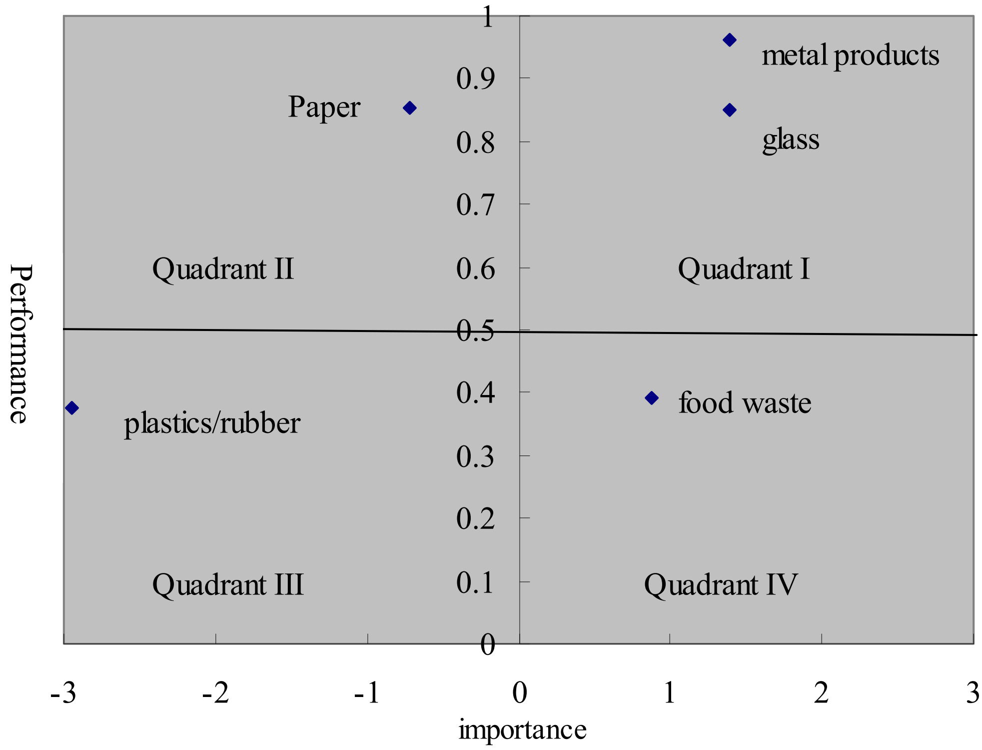

Figure 3. the map of IPA for waste fractions selected

Table 1. Amount of MSW collected, disposed, and recycled unit: tonnes

	MSW generated	MSW disposed	Waste recycled			
			Sub-total	Recyclables	Food waste	Bulk waste
1998	8,992,240	8,880,487	111,753	111,753	n.a.	n.a.
1999	8,715,575	8,565,699	149,876	149,876	n.a.	n.a.
2000	8,353,368	7,875,511	477,856	477,856	n.a.	n.a.
2001	7,839,173	7,254,841	584,333	584,333	n.a.	n.a.
2002	7,601,958	6,723,639	878,319	878,319	n.a.	n.a.
2003	7,355,335	6,139,050	1,216,285	1,048,981	167,304	n.a.
2004	7,554,870	5,862,890	1,691,980	1,392,715	299,265	n.a.
2005	7,775,064	5,525,253	2,249,811	1,756,035	464,201	29,575
2006	7,738,531	5,032,672	2,705,859	2,107,037	570,176	28,646
2007	7,975,686	4,873,237	3,102,450	2,408,429	662,791	31,230
2008	7,607,798	4,374,154	3,233,645	2,497,985	691,194	44,466
2009	7,729,231	4,223,484	3,505,748	2,718,803	721,472	65,473
2010	7,870,665	4,072,603	3,798,062	2,948,681	769,164	80,217
2011	7,485,229	3,610,848	3,874,380	2,982,855	811,199	80,326
2012	7,470,569	3,379,390	4,091,180	3,167,656	834,541	88,983

Table 2. The test of diffusion effects

	Aggre. recyle.	Food waste	Bulk waste	paper	metal	glass	plastics/ rubber
α_0	0.0188^{**}	0.0221^{**}	-0.0052	0.0096^{**}	0.0034^{*}	0.0019^{*}	0.0022^{*}
α_1	0.1921^{**}	-0.1212	2.1378	0.1828^{*}	0.2962^{**}	0.0467	0.1324
α_2	-0.4866^{**}	-0.5186	-149.12	-0.8099^{*}	-3.3624^{**}	-1.3357	-3.3334
R^2	0.3445	0.7634	0.4721	0.2689	0.4481	0.0087	0.1292
Adj. R^2	0.2254	0.6846	0.2082	0.1360	0.3477	-0.1715	-0.0291
obs. no.	14	9	7	14	14	14	14

Table 3. The estimates of external force, internal force and ceiling of recycling rate

	recyclables	paper	metal products
Coefficient of internal force, $\hat{p}$	0.2316	0.2183	0.3311
Coefficient of external force, $\hat{q}$	0.0395	0.0355	0.0349
Ceiling of recycling rate, $\hat{M}$	0.4759	0.2696	0.0985
Recycling rate in 2012	0.4240	0.2299	0.0947
Performance of recycling	89.09%	85.27%	96.17%

科技部補助計畫衍生研發成果推廣資料表

日期:2016/10/18

科技部補助計畫	計畫名稱: 資源回收政策再審思：廠商延伸性責任的實施
	計畫主持人: 陳中獎
	計畫編號: 104-2410-H-343-003- 學門領域: 作業研究／數量方法

無研發成果推廣資料

104年度專題研究計畫成果彙整表

<table>
<tr><td colspan="5">計畫主持人：陳中獎</td><td colspan="3">計畫編號：104-2410-H-343-003-</td></tr>
<tr><td colspan="8">計畫名稱：資源回收政策再審思：廠商延伸性責任的實施</td></tr>
<tr><td colspan="5">成果項目</td><td>量化</td><td>單位</td><td>質化
（說明：各成果項目請附佐證資料或細項說明，如期刊名稱、年份、卷期、起訖頁數、證號...等）</td></tr>
<tr><td rowspan="19">國內</td><td rowspan="6">學術性論文</td><td colspan="3">期刊論文</td><td>0</td><td rowspan="2">篇</td><td></td></tr>
<tr><td colspan="3">研討會論文</td><td>0</td><td></td></tr>
<tr><td colspan="3">專書</td><td>0</td><td>本</td><td></td></tr>
<tr><td colspan="3">專書論文</td><td>0</td><td>章</td><td></td></tr>
<tr><td colspan="3">技術報告</td><td>0</td><td>篇</td><td></td></tr>
<tr><td colspan="3">其他</td><td>0</td><td>篇</td><td></td></tr>
<tr><td rowspan="11">智慧財產權及成果</td><td rowspan="3">專利權</td><td rowspan="2">發明專利</td><td>申請中</td><td>0</td><td rowspan="11">件</td><td></td></tr>
<tr><td>已獲得</td><td>0</td><td></td></tr>
<tr><td colspan="2">新型/設計專利</td><td>0</td><td></td></tr>
<tr><td colspan="3">商標權</td><td>0</td><td></td></tr>
<tr><td colspan="3">營業秘密</td><td>0</td><td></td></tr>
<tr><td colspan="3">積體電路電路布局權</td><td>0</td><td></td></tr>
<tr><td colspan="3">著作權</td><td>0</td><td></td></tr>
<tr><td colspan="3">品種權</td><td>0</td><td></td></tr>
<tr><td colspan="3">其他</td><td>0</td><td></td></tr>
<tr><td rowspan="2">技術移轉</td><td colspan="3">件數</td><td>0</td><td>件</td><td></td></tr>
<tr><td colspan="3">收入</td><td>0</td><td>千元</td><td></td></tr>
<tr><td rowspan="15">國外</td><td rowspan="6">學術性論文</td><td colspan="3">期刊論文</td><td>0</td><td rowspan="2">篇</td><td></td></tr>
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<tr><td rowspan="9">智慧財產權及成果</td><td rowspan="3">專利權</td><td rowspan="2">發明專利</td><td>申請中</td><td>0</td><td rowspan="9">件</td><td></td></tr>
<tr><td>已獲得</td><td>0</td><td></td></tr>
<tr><td colspan="2">新型/設計專利</td><td>0</td><td></td></tr>
<tr><td colspan="3">商標權</td><td>0</td><td></td></tr>
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<tr><td colspan="3">品種權</td><td>0</td><td></td></tr>
<tr><td colspan="3">其他</td><td>0</td><td></td></tr>
</table>

	技術移轉	件數	0	件	
		收入	0	千元	
參與計畫人力	本國籍	大專生	5	人次	
		碩士生	0		
		博士生	0		
		博士後研究員	0		
		專任助理	0		
	非本國籍	大專生	0		
		碩士生	0		
		博士生	0		
		博士後研究員	0		
		專任助理	0		
其他成果 （無法以量化表達之成果如辦理學術活動、獲得獎項、重要國際合作、研究成果國際影響力及其他協助產業技術發展之具體效益事項等，請以文字敘述填列。）					

科技部補助專題研究計畫成果自評表

請就研究內容與原計畫相符程度、達成預期目標情況、研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性）、是否適合在學術期刊發表或申請專利、主要發現（簡要敘述成果是否具有政策應用參考價值及具影響公共利益之重大發現）或其他有關價值等，作一綜合評估。

1. 請就研究內容與原計畫相符程度、達成預期目標情況作一綜合評估

   ■達成目標

   □未達成目標（請說明，以100字為限）

   　　□實驗失敗

   　　□因故實驗中斷

   　　□其他原因

   說明：

2. 研究成果在學術期刊發表或申請專利等情形（請於其他欄註明專利及技轉之證號、合約、申請及洽談等詳細資訊）

   論文：□已發表　■未發表之文稿　□撰寫中　□無

   專利：□已獲得　□申請中　■無

   技轉：□已技轉　□洽談中　■無

   其他：（以200字為限）

3. 請依學術成就、技術創新、社會影響等方面，評估研究成果之學術或應用價值（簡要敘述成果所代表之意義、價值、影響或進一步發展之可能性，以500字為限）

   本計畫不僅提出理論性架構，探討資源垃圾的相關議題，以及政府制訂政策時所必須考慮的因素，同時，也分別針對國內資源垃圾的回收情形以及各種資源垃圾的回收績效，提出分析與檢討。在學術上成就來說，本計畫開創了一扇窗，結合理論與實務需要，務實的以臺灣的垃圾資源現況以及資源回收的數據作依據，分析影響資源垃圾回收的因素，並透過數學模式的建構，分析制訂最佳資源稅的水準。

   由於本計畫在方法論上有學理根據，在資料的應用上，也是以最新最可靠的官方資料，如此，所產生的結果在實務應用上，當具有非常務實的效益。利用過去資源垃圾回收的數據，用來檢視政府過去的垃圾管理政策，更能一針見血診斷出政策制訂的盲點。

4. 主要發現

   本研究具有政策應用參考價值：■否　□是，建議提供機關

   （勾選「是」者，請列舉建議可提供施政參考之業務主管機關）

   本研究具影響公共利益之重大發現：■否　□是

   說明：（以150字為限）

   本計畫研究結果發現大多數之可回收資源垃圾，回收績效良好，但是，廚餘以及大型資源垃圾尚有改善空間。可回收資源垃圾的回收績效中，廢金屬表現最

好。其次，則是廢紙、廢玻璃等。透過重要性績效分析，本計畫建議政府應該加強廚餘的回收，並將之用於有機肥料、biogas等的生產，以增加資源的使用效率。