Predicting recycling efficiency

- Multiple regression modeling of the recycling rates of Tetra Pak’s beverage Cartons

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Abstract

Tetra Pak is the world's largest producer of beverage cartons with an annual worldwide production of about 150 billion packages. They work actively with improving their recycling efficiency by setting recycling rate goals for the next three, six and nine years for each market. These goals have so far been educated guesses and there is a need for investigating what drives and predicts recycling efficiency. What factors affect how good a country is at recycling its paper packaging? And, if these factors are known, would it be possible to predict the development of recycling rates by looking at the development of these factors?

In this thesis I investigate these "predictors" influencing recycling efficiency and build models using multiple regression analysis with the aim of explaining as much as possible of the inbetween countries variation of recycling rates. Socio-economic predictors such as Gross Domestic Product (GDP), Education (EDU) and Urban population size (URB), together with Environmental concern (ENV), were tested against recycling rates measured for Tetra Pak´s beverage cartons. The model with the best fit (R^2=0.382) consisted of GDP and Environmental concern, although only GDP turned out to be significant. Conclusively, GDP is a good predictor of recycling efficiency where the others were not. I encountered considerable problems with multicollinearity and lack of good quality data, leaving me quite critical towards the possibility of creating trustworthy models in the future.

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1. Introduction

Vast amounts of beverage cartons are produced annually across the world. When the packaging has fulfilled its purpose it becomes waste that is to be disposed of. One of the better ways of doing this is to recycle the waste (Kaseva & Gupta 1996). What was once useless waste can then be viewed as a valuable resource and used repeatedly. Recycling packages is both environmentally and economically desirable as it is energy and resource-efficient and thereby has less harmful effects, such as deforestation and consumption of energy from fossil fuels (Kaseva & Gupta 1996).
The definition of recycling is "*any recovery operation by which waste materials are reprocessed into products, materials or substances, whether for the original or other purposes*." (Directive 2008/98/EC) and this definition is also used in the thesis.
Tetra Pak is the world largest producer of beverage cartons and annually puts about 150 billion beverage cartons on the world market (Hansson, 30/5 2011). Being one of the leading companies in their line of work means that they have considerable environmental impact and with that comes great responsibility. Therefore Tetra Pak works actively with environmental activities where the recycling of the beverage cartons is a field of great importance (Abreu, 15/3 2011). For each market Tetra Pak has their own internal recycling rate goals which they strive to achieve. These goals are set in plans of three, six and nine years and have so far primarily been educated guesses from the main manager of each market. When looking at the different markets where Tetra Pak is established in,

it is clear that there are substantial differences between the actual recycling rates. The rates, as available for this research, span between a few to about 70 percent, where the leading countries are Belgium, Luxembourg and Germany and the bottom ones are Venezuela, Indonesia and Poland, see Figure 1. What is it that makes these countries recycling activities more or less effective? What factors affect how good a country is at recycling its packaging? And, if these factors are known, would it be possible to predict the development of recycling rates by looking at the development of these factors?

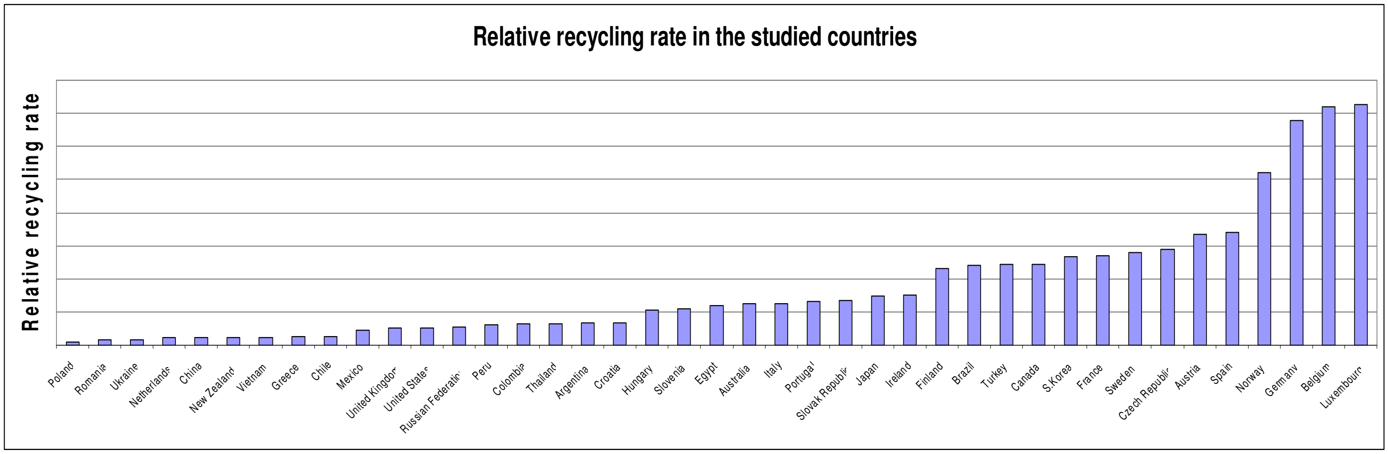

Figure 1. Packaging recycling rates (2006) for all countries participating in the models. The y-axis shows relative recycling rate because the actual numbers are confidential.

1.1 Aim, scope and outline

The aim of this thesis is to investigate these factors influencing recycling efficiency and build a model that explains as much as possible of the variation between countries. This can then be used to predict future recycling rates, both by Tetra Pak and by others. For Tetra Pak this would ease the process of interpreting the recycling development of different markets and also to make better educated guesses about what recycling rates are reasonable goals to work against in the future.

Recycling efficiency can be studied at different levels; household, community or municipal levels are all examples of previously frequently studied levels. In this thesis, the work is performed without consideration of these levels. This thesis is instead limited to a comparative approach on a country-level basis, focusing on socio-economic predictors and environmental concern. Predictors such as Gross Domestic Product (GDP), Education (EDU), Environmental concern (ENV) and Urban population size (URB) were tested against recycling rates measured for Tetra Pak's beverage cartons. Based on a literature study, these predictors were all hypothesized to relate positively to recycling efficiency, i.e., the greater values of the variables, the greater recycling efficiency.

The following text will first give background information on the history of waste management and what drivers are responsible for the development of today's waste management systems (WMSs). Tetra Pak's cartons and some of the previous research on predictive models are also included. After this follows a desription of the method used, followed by the results. Finally there is a discussion of the results and what they imply for Tetra Pak and further studies.

2. Background

2.1 History of recycling and waste management

Before 1800

The history of waste management and recycling stretches as far back in time to where people started to live in larger communities. Waste has always been generated around people and in larger communities waste became a problem (wasteonline, 14/6 2011). In cities it piled up in the streets, creating foul smells and health problems. In the old societies, everything that still held value was reused or sold, and the rest was either left in the streets or occasionally removed by employed workers (e.g. "rakers" in 18th century London) (Girling 2005 and Wilson 2007).

1800 - 1960

During the 19th and first half of the 20th century different drivers pushed the gradual development of more formal WMSs (Wilson 2007). The health issue was an important driver for the cities officials to take care of the waste (Girling 2005). Focus was still on collecting and getting rid of the waste. Other driving forces were resource scarcity and technology development, especially during the two World Wars. The disposal of the waste was mostly uncontrolled, i.e., happened by dumping or burning, creating new problems such as air and water pollution (Wilson 2007).

1960 -

Waste management appeared on the political agenda first in the 1960s and 70s when environmental protection and energy savings introduced themselves as new drivers. The first step was to get control over the waste disposal by e.g. introducing daily covering of landfills and installing electrostatic precipitators for dust control in the incineration facilities. In Europe, an important driver has been the introduction of the policy instrument called *the waste hierarchy* in 1977 (Wilson 2007). It calls for a move away from disposal to a more sustainable option of reducing the amount of waste, reuse and recycle the waste and lastly recovering the energy by incineration. This hierarchy is linked to a driver of the past, the value of waste as a resource and is seen as one of the first steps in moving away from an *end-of-pipe*[1] approach to a more integrated concept of waste management (Wilson 2007). During the 1980s there was a period focusing on development of new technology to further reduce emissions and odours from landfills and incineration. The technology development has since then moved along other phases and continues today when the European Union requires the use of *best technique available*[2]. A more recent driver that has emerged is climate change which has resulted in

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[1] End-of-pipe approach is a policy instruments defined as "*Technologies such as scrubbers on smokestacks and catalytic convertors on automobile tailpipes that reduce emissions of pollutants after they have formed*" (European Environmental Protection Agency (EEA), 12/6 2011)

[2] Policy instruments defined as "*The most effective and advanced stage in the development of activities and their methods of operation which indicate the practical suitability of particular techniques for providing in*

a move from landfilling of biodegradable waste to a renewed focus on energy recovery from incineration (Wilson 2007).

Another part of the integrated approach on waste management is a shift in responsibility. Waste management has up to recently been the responsibility of the municipalities, but has been shifted towards the private sector by the introduction of *extended producer responsibility*. This means that the producer of products also has a responsibility when the product has fulfilled its purpose, i.e., the private sector has to be engaged in collecting and recycling its used products. This was originally a European phenomenon, but has today extended to the OECD and beyond (Wilson 2007).

Another recent driver in the development of recycling is public awareness. The development towards a more integrated approach of resource management, with reuse, higher recycling rates, home composting etc., demands a change in behaviour of the people involved (Sharp 2006).

2.1.1 WMSs in different shapes

Today countries can be placed somewhere along the above outlined scale of waste management development, indicating differences in what their WMS looks like (Wilson 2007). Countries continuously develop and the measure of what is a developed country shifts over time. This means that there is no discrete line separating "rich" and "poor" countries (Wilson 2009). Still, for simplicity, the terms developing and developed countries are used in this thesis because of the fact that developing countries often have an extensive informal WMS. The drivers of informal WMSs differ substantially from those of formal systems in that they are driven by the value of recyclable wastes and that they lack the financial support that formal WMSs may receive from the government officials (Wilson *et al*. 2009). Some developing countries may still have to focus on getting rid of the waste and may not have the luxury of focusing on a "resource approach", placing them in the same situation as European countries were in before the 1960s (Wilson *et al.* 2001).

2.1.1.1 Developing countries

The value of waste as a resource creates the ability of making a living by collecting and selling waste for the urban poor, opening up for an informal waste management (Wilson *et al*. 2006). These informal systems are a common phenomenon in developing countries and are based upon the work of poor marginal groups such as gypsies, immigrants, rural migrants and religious minorities (Berthier 2003). These groups earn their income by picking waste on dumpsites or collecting household waste from door to door or from the streets. This is then sorted and pre-processed to gain more money upon selling it to intermediate dealers or local recyclers (Wilson *et al.* 2006). The recycling efficiency of a specific waste category depends on the income levels in the country, the need for secondary material and the existence of local and national markets, prices of virgin

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principle the basis foremission limit values designed to prevent and, where that is not practicable, generally to reduce emissions and impact on the environment as a whole" (Directive 96/61/EC of 24 September 1996) materials, the level of governmental intervention (regulatory and financial) and international trade of secondary materials and international treaties (Wilson *et al*. 2006). China and India are examples of countries that are major industries that depend strongly on the availability of secondary materials (Wilson *et al*. 2006).

An informal WMS can be quite efficient and cheap for the municipal officials, with high collection rates and good coverage over areas where there is no municipal system in place. In some developing countries, current recycling rates of 20-50% compares well with those of some European and North American countries (Wilson *et al*. 2009). The Zabbalean in Cairo in Egypt is one example of a high performing informal WMS that may achieve an 80 percent collection rate (Coad 2003 and Wilson *et al*. 2009). Even though the informal recycling programmes often are very successful in collecting and recycling materials that are valuable to them, difficulties may arise when dealing with certain waste categories. What is not easily turned into value, sometimes by lacking recycling infrastructure or enough volume, will not be collected. This might be the case with beverage cartons (Lindqvist, T. 11/6 2011).

Downsides of these informal systems are that the working conditions for these scavengers are often very poor with bad sanitation, no access to urban services such as water supply and sewage and no safety networks (Wilson *et al*. 2006). Most western countries have phased out their earlier informal WMS and now have formal systems in use. This also means that they have struggled the past 15 years with rebuilding their recycling rates to former levels to meet increasing recycling goals (Wilson *et al*. 2006).

When developing countries progress economically, there is often a change in consumption patterns which leads to an increase in the amount of generated waste (Medina, 1997; Misra & Pandy, 2005). The combination of economic growth and increasing amounts of waste cause problems for the public sector in handling the waste management. This leads to a decrease in the recycling rates which is shown as a negative correlation between economic development and recycling rates by van Beukering and Bouman (2001). A rapidly evolving economy also uses the easy assessable primary materials instead of the more “laborious” recycled material which hampers the development of more efficient recycling programs (van Beukering and Bouman, 2001).

2.1.1.2 Developed countries

The formal WMSs in developed countries come in many shapes, but have some characteristics in common. A typical formal recycling programme consists of collection, separation, cleaning and reprocessing and results in diversion of material from the waste stream to material recovery (Marsh & Bugusu 2007). The responsibility for the collection of the recyclable part of the household waste is often shared by the municipalities and the private sector through a legal requirement of *(extended) producer responsibility (EPR)*. The concerned industries often form common organisations to handle the collection and then sell the recyclable waste to recycling companies. The municipalities may also outsource the collection part. If there is separation of the household waste, it is often performed by the household. The waste is then either collected outside every household (kerb-side collection) or transported (by the household) to a station where it is picked up by a hired contractor (Marsch & Bugusy 2007).

2.2 TP´s beverage cartons and recycling

Tetra Pak produces a range of different packages for beverages based on the same concept. Carton made in paper mills are coated with plastic foil, often polyethylene or polypropylene. If the package is to be aseptic then also a layer of aluminium is added. With these two or three layers the carton is printed with the design of the customer and then transported to the filling facilities (Tetra Pak, 31/5 2011).
Recycling of beverage cartons is often carried out in a paper mill through recovery of the fibre. At the mill the cartons and other paper are put in a large vat of water where they are swirled around. This makes the fibres separate and absorb water, resulting in a thick slurry of saturated fibres. Any contaminants such as plastics will either sink or float and can be removed from the process by scraping or sieving. The fibres can then be reshaped into a new product e.g. printing paper, paper bags or board for corrugated boxes (Tetra Pak, 31/5 2011). The plastic coating and aluminium can to some extent be recycled into new materials used for low-cost housing materials or be used as fuels in cement kilns (Tetra Pak, 31/5 2011).

2.3 Previous research on predictive models

The research relating to recycling efficiency is mainly directed within two areas; evaluation of the performance of different recycling systems and the study of factors determining ecological behaviour in household waste separation. Recently there has also been a shift of focus from developed to developing countries where there is accelerating economic growth (Schoot Uiterkamp *et al*. 2010).
Schoot Uiterkamp *et al*. (2010) evaluated the sustainability of the waste management of two countries, Tanzania and India. Both Tanzania and India are classed as Lower Middle Income Countries (LMICs), but India has progressed further economically and industrially. The comparison of the WMSs highlights the differences in sustainability between low-industrialised LMICs and rapidly industrialising LMICs. In doing the evaluation, Schoot Uiterkamp *et al*. developed a model based upon seven major criteria:

- Governmental involvement;
- Economic conditions;
- Social conditions;
- Production techniques;
- Technological efforts;
- International trade legislation.

This model can be used when trying to identify geographical patterns in recycling efforts among countries, markets and cultures and also to distinguish differences in recycling between countries with different levels of economic development (Schoot Uiterkamp 2010).

Suttibak and Nitivattananon (2008) used multiple regression analysis to assess factors influencing the performance of recycling programs on a local level in Thailand. They tested economic, financial, institutional and technical aspects of different local recycling programs such as composting facilities and community and school garbage banks. The conclusions were that factors such as source separation, provision of free organic waste bins, cooperation with NGOs[3] and economic support from the national government contributed significantly to a good performance (Suttibak and Nitivattananon 2008).

Miranda and Blanco (2010) did a study on paper waste where they correlated different socio-economic predictors and different measures of environmental awareness to recycling rates of paper. GDP was correlated under the presumption of the traditional suggestion that affluence and education are the main socio-economic predictors relating to recycling success (Sidique *et al.* 2010; Coggins 1994; Martin *et al*. 2006). Although this assumption is not without controversy in other research (Saphores *et al*. 2009), in this case, GDP was found to be a significant predictor, while education was not. The reason for the insignificance of the latter predictor was proposed to be the type of indicator chosen (public expenditure on education), which shows not the quality of the education, but merely the amount of money spend on public schools. Population density was also correlated against collection rate. This was based upon the fact that in some cases, low population density is a barrier for high recovery rates, because the collection of recovered paper in a widely dispersed area is not economically feasible (Miranda & Blanco 2009). However, population density was in the study proven an insignificant factor.
Environmental awareness, measured in different ways, were also tested and were found to be (in some cases) significant. Environmental awareness was based on a concept explaining how citizen participation is a keystone for success of any recycling scheme. The participation in recycling programs is greatly influenced by the motivation of the citizens and the motivation in turn is fuelled by the feeling of having an impact on the world and contributing to a healthier environment (Bolaane 2006, Bartelings & Sterner 1999).
Samdahl and Robertson (1989) investigated motivators of environmental concern and built their factor out of three measures: perception of an environmental problem, support for environmental regulations and ecological behaviour (Samdahl & Robertson 1989).

2.4 Potential predictors of recycling efficiency

Gross Domestic Product – GDP

GDP is the collective value of all services and goods that are produced in a country in a year. It is the most common way to describe economic growth (as change in GDP over time) and serves as a measure of a country's affluence[4] (Ekonomifakta 22/5 2011). Even though GDP is often questioned as a proxy for welfare, it is frequently used for economic development and it is readily available for all countries and any recent year (van den Bergh, 2010).

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[3] Non Governmental Organisations

[4] GDP can be measured in three ways: *the product approach*, *the income approach* and *the expenditure approach*, all of which should give the same result. The production approach is the most direct approach and consists of the total of the production of every company or enterprise in a specific year. The expenditure approach is instead measuring the value of people's total expenditures in buying goods or services and is working under the principle that all the product and services have to be bought by someone. The income approach measures all the producers' incomes which is supposed to be equivalent to the value of their products (Statistical manual, the World Bank, 22/5 2011).

Education – EDU

Education can be measured in numerous ways depending on the aim of the indicator and the amount of available data. Examples are expenditure on public schools, entry rates in tertiary education, results from standardised tests, teachers' salaries and literacy rates in specific age groups (The World Bank, 22/5 2011).

Urban population – URB

Low population density could, as mentioned above, act as a potential barrier for a good recovery rate of paper. The situation is the same as with paper packaging which is why this indicator is included in the model. Population density is in this case measured as percent of the population that is living in urban areas.

Environmental concern – ENV

Environmental concern is an indicator solely produced for this paper. It is the sum of the results from three questions or statements posed in a worldwide questionnaire by the World Value Survey. The questions, which will be presented in Chapter 3.1, were chosen based on the finding of Samdahl and Robertson (1989) and Bartelings & Sterner (1999) who investigated social determinants of environmental concern. They found that the determinants of environmental concern were three: support for environmental regulation, the perception of an environmental problem and ecological behaviour.

3. Method

3.1 Data collection and manipulation

Data on recycling rates for TP's packaging were received from Tetra Pak (Tetra Pak, Recycling rates 2002 – 2010). Data on GDP and level of education were attained from the online databases of the World Bank (The World Bank open database, 20/3 2011) and the OECD (OECD statistics, 23/3 2011). Data on Environmental concern were attained from the online database of the World Value Survey (World Value Survey 1981-2008), where the latest available and most extensive data was from 2006. Because of this, all other data were taken from this year. To attain a minimum sized set of data, some exceptions were necessary. In such cases, the closest adjacent previous year was chosen. With one exception (where data from 1999 had to be chosen), all values were from the 21st century.

In search of better linear relationships and to avoid statistical problems when using rates and percentages (Gordon, 2010), recycling rate, GDP, Education and Urban population data were transformed from percent to proportions and then to logarithmic values. As GDP data, the expenditure approach and per capita was chosen. As indicators of education, three measurements were tested: Public expenditure on education (as % of GDP), results from standardised tests (PISA) and enrollment rate in tertiary education. Of these three, the standardised tests should be the one saying something about the quality of a country´s education. In spite of this, the last proxy was chosen to be tested in the models because it correlated significantly with the recycling rate and contained the most

data. This way, the amount of data and a better linear relationship was prioritised over a decreased proxy quality.
The predictor Environmental concern was put together by combining three statements corresponding to the determinants in chapter 2.4. The statements were found in the 2006 questionnaire of the World Value Survey and were combined into a single predictor:

Statements 1. Increase in taxes is ok if used to prevent environmental pollution
2. Environmental problems in the world: Pollution of rivers, lakes and oceans.
3. Active/Inactive membership of environmental organisation

The respondents were given multiple choices on how strongly they agree or disagree with the statement, how serious they thought of the mentioned environmental problem, and if they were active, inactive or not at all members of an environmental organisation. To be able to compare the answers between countries, the alternatives were weighed (for this study) accordingly:

1. agree: strongly disagree: -2 points, disagree: -1 points, agree: 1 point, strongly agree: 2 points
2. not serious at all: -2 points, not very serious: -1 points: somewhat serious: 1 point, very serious: 2 points
3. not member: 0 points, inactive member: 1 point, active member: 2 points

The points were multiplied with the percent of respondents that had answered a specific answer, giving a total for each country and question.
Environmental concern as a predictor of recycling efficiency is based upon the assumption that people act according to their beliefs. The respondents who answer that they behave in an ecological way and believe in protecting the environment should thereby also be the ones who sort and recycle their household waste, helping the system into a higher recycling rate. Though it is known from previous studies that people overstate their willingness to act in an environmentally sound way in surveys (Dahlén 2008), the predictor is still likely to reflect the relative preparedness and likeliness of real action.

3.2 Statistics

The statistics were run using multiple regression analysis in SPSS, PASW statistics for Microsoft Windows 2007.
The models were built using multiple regression analysis with simultaneous regression. Multiple regression analysis is used when there is one dependent (effect-) variable and several independent (cause-) variables (Leech *et al*. 2008). In this study, Recycling rate is the dependent variable and the predictors GDP, Environmental concern, Education rate and Urban population rate is the independent variables. Multiple regression analysis is a good way of posing and answering the question: “What is the best predictor of … “ (StatSoft, 25/5 2011). When using multiple regression analysis, there are some main assumptions or requirements that need to be fulfilled:

- The relationship between the dependent and the independent variables is assumed to be linear. Minor deviations from this assumption does not affect the result to any great extent but larger deviations should be avoided (StatSoft, 25/5 2011).
- The independent variables, the predictors, must be independent of each other; hence there should be no intercorrelation between the predictors. Violation of this requirement will create problems with multicollinearity[5] which could cause misleading results. Tolerance and VIF are two measures that tells if there is multicollinearity. Tolerance equals to 1/VIF and if tolerance-values are low ($<1-R^2$), then there is a problem with intercorrelating predictors (Leech *et al*. 2008).
- The errors should be normally distributed and should not correlate with the independent variables (Leech et al 2008).

These assumptions are tested in Chapter 4.3.

Multiple regression works in the same way as linear regression but the "best fit" line is made up by the slopes of several independent variables (Dytham 2011).
In building the models, the regression equation of each of the models is shown as:

$$Y = a + B_1 * X_1 + B_2 * X_2 + B_3 * X_3 ... + B_i * X_i$$

where

Y is the dependent variable, i.e., the Recycling rate
a is the intercept (where the line cuts the y-axis)
B is the constant describing the slope
X is the independent variables: GDP, EDU, URB

The method of simultaneous regression[6] is a method used in SPSS where the computer tells the program to consider all variables at the same time (Leech et al. 2008).

3.3 Models

When building the models, every added variable should correspond to 10-20 times as much data (StatSoft, 25/5 2011). This way, if four variables are supposed to be tested, the data set should be at least 40 figures large. Other research claims that even larger data sets are preferred (N>50 + 8* the number of independent variables) (Berger, 2003). The data on Environmental concern did only bring forth complete data on 24 countries, making it only possible to test two variables. To handle this, the data set was divided into two parts, with one smaller part containing (N = 24) environmental concern and one socio-economic variable, and one larger one (N = 43) where all socio-economic variables could be tested. To handle the effect of small data sets, the adjusted R square value (instead of R square) was used to evaluate the fit of the model as has been suggested by Berger (2003). In the larger data set two outliers were identified (Indonesia and

[5] "Relationship between… more than two variables. Variables exhibit complete collinearity if their correlation coefficient is 1 and a complete lack of collinearity if their correlation coefficient is 0" (Belsley et al. 1980).
[6] In SPSS referred to as "Enter".

Venezuela) and removed making N = 41 for the large data set and N=22 in the smaller one (out of the two outliers, only Indonesia had available data on Environmental concern).

In total four models were tested against recycling efficiency;

1. GDP, Environmental concern
2. GDP, Urban population rate and Education
3. GDP, Urban population rate
4. GDP, Education

In search of better linearity between the dependent and the independent variables, a second division of the data was made resulting in a smaller data set (N=23) consisting of member countries of the European Union and a larger data set containing all available countries (the same as the previous larger data set where N equals 41). The reason for testing one further division is that the EU has legislation for packaging waste which is comprehensive, while many other countries do not have it, or it is less comprehensive (Lindqvist, T., 12/6 2011). Countries that have less extensive environmental regulation are less driven towards higher recycling rates and by removing these countries I might improve the linear relationship between the predictors and Recycling efficiency. This division is tested for GDP in Chapter 4.4.

4. Results

Multiple regression analysis was conducted to determine the best linear combination of GDP, Environmental concern, Education and Urban population rate, trying to predict recycling efficiency.

Assumptions of linearity, no intercorrelation and normally distributed errors were checked and are discussed in Chapter 4.3.

4.1 The small data set

The multiple correlation coefficient, R, in Model 1 is 0.660, indicates how strongly the predictors are related to recycling success (Table 1). The value stretches between -1, 0 and 1, where 0.660 is considered a fairly high positive correlation (Leech *et al*. 2008). The adjusted R square value of 0.382 indicates that about 38 percent of the variation in the data can be explained by GDP and Environmental concern, see Table 1. The ANOVA proved to be significant, telling us that the null hypothesis posed by the ANOVA (the regression equalling zero), can be rejected, see Table 9. This in turn, means that the model significantly predicts recycling efficiency (Leech *et al*. 2008).

Table 1. Model 1, containing GDP and Environmental concern, had an adjusted R square of 0.382, i.e., about 38 percent of the variation can be explained by the model.

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.660[a]	.435	.382	.540

a. Predictors: (Constant), GDP, Environmental concern

b. Dependent Variable: Recycling rate

The correlation matrix (Table 2) showed a significantly strong, positive correlation between Recycling rate and GDP ($r=0.652$, $p<<0.001$) but no significance between recycling rate and Environmental concern where the relationship even showed to be negative ($r = -0.130$, $p>>0.05$). The coefficients of the regression equation (Eq. 1) of model 1 is shown in Table 3 under standardised coefficients, beta. Here the coefficient of GDP was significant, but Environmental concern was not, indicating that the coefficient in the regression equation of the latter predictor is uncertain. The regression equation was put together as:

$$Y = -3.447 + (-0.104 * ENV) + 0.647 * GDP \qquad \text{(Eq. 1)}$$

Table 2. Pearson correlations between Recycling rate and the predictors, also including correlations between the variables. GDP was significantly correlated to recycling rate.

Correlations

		Recycling rate	Environmental concern	GDP
Pearson Correlation	Recycling rate	1.000	-.130	.652
	Environmental concern	-.130	1.000	-.041
	GDP	.652	-.041	1.000
Sig. (1-tailed)	Recycling rate	.	.273	.000
	Environmental concern	.273	.	.425
	GDP	.000	.425	.

The zero-order and partial correlations in Table 3 was for Environmental concern -0.130 and -0.136 and for GDP 0.652 for both. The zero-order correlation tells us about the relationship between the dependent and the independent variable, while ignoring the influence of the other independent variables. Partial correlation describes the correlation between the dependent variable and an independent variable when the linear effects of the other independent variables have been removed (Leech *et al*. 2008).

Table 3. The coefficient for Environmental concern was -0.104 and for GDP 0.647, where only GDP proved to be significant.

Coefficients[a]

Model	Unstandardised Coefficients		Standardised Coefficients	t	Sig.	95.0% Confidence Interval for B		Correlations			Collinearity Statistics	
	B	Std. Error	Beta			Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
1 (Constant)	-3.447	1.179		-2.922	.008	-5.900	-.994					
Environmental concern	-.002	.004	-.104	-.631	.535	-.010	.005	-.130	-.136	-.104	.998	1.002
GDP	.734	.186	.647	3.946	.001	.347	1.121	.652	.652	.647	.998	1.002

a. Dependent Variable: Recycling rate

4.2 The larger data set

Of the models in the larger data set, (testing only socio-economic variables), model 4 (GDP + EDU) was the one having the best fit with an adjusted R square of 0.254 and a multiple regression coefficient (R) of 0.541, see Table 3. Model 2 (R = 0.541) and 3 (R = 0.519) followed closely with adjusted R square values of 0.233 and 0.230, see Tables 4 and 5. The ANOVA showed significant results for all models, see Table 9. The correlation matrix (Table 7) showed significant correlations between recycling rate and GDP, and between recycling rate and Urban population rate.

Table 4. Model 2 (consisting of the predictors GDP, EDU and URB), showing a fairly poor fit with an adjusted R square of 0.233.

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
2	.541[a]	.292	.233	.427

a. Predictors: (Constant), EDU (tertiary enrollment rate) , URB (urban population rate), GDP

b. Dependent Variable: Recycling rate

Table 5. Model 3 (consisting of the predictors GDP and URB), showing a fairly low poor with an adjusted R square value of 0.230.

Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
3	.519[a]	.269	.230	.429

a. Predictors: (Constant), URB (urban population rate), GDP

b. Dependent Variable: Recycling rate

Table 6. Model summary for a model consisting of the variables GDP and EDU showing the best fit of all models in the large data set (still a fairly poor one though) with an adjusted R square value of 0.254.

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Model Summary[b]

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
4	.541[a]	.292	.254	.422

a. Predictors: (Constant), EDU (tertiary enrollment rate) , GDP

b. Dependent Variable: Recycling rate

Table 7. The Correlation matrix of the predictors in model 2 showed that there is a significant,and positive correlation between Recycling rate and GDP and URB. There is no significance between Recycling rate and EDU but instead a significant correlation between GDP and both URB and EDU, indicating that there might be a problem with intercorrelation.

Correlations

		Recycling rate	GDP	URB (urban population rate)	EDU (tertiary enrollment rate)
Pearson Correlation	Recycling rate	1.000	.518	.296	.086
	GDP	.518	1.000	.610	.432
	URB (urban population rate)	.296	.610	1.000	.337
	EDU (tertiary enrollment rate)	.086	.432	.337	1.000
Sig. (1-tailed)	Recycling rate	.	.000	.032	.299
	GDP	.000	.	.000	.003
	URB (urban population rate)	.032	.000	.	.017
	EDU (tertiary enrollment rate)	.299	.003	.017	.

The regression coefficients for the regression equations (Eq. 2) were significant for GDP, but not for the other two, indicating that the GDP coefficient is the only one to be trusted, see Table 8. The regression equation for model 2 was put together as:

$$Y = -3.509 + 0.599 * GDP + (-0.13 * URB) + (-0.169 * EDU) \quad \text{(Eq. 2)}$$

The Tolerance values was lowest for GDP (0.570) and Urban population rate (0.621) and with an R square for model 2 of 0.292, the level where multicollinearity may become a problem equals to 1 minus 0.292 i.e., 0.708. Values lower than this indicates the presence of intercorrelation, which is the case with GDP and URB.

Table 8. In model 2 only GDP proved to have a significant coefficient (t=4.147, p<0.001) indicating that this is the only coefficient in the regression equation that can be trusted.

Coefficients[a]

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Correlations			Collinearity Statistics	
	B	Std. Error	Beta			Lower Bound	Upper Bound	Zero-order	Partial	Part	Tolerance	VIF
2 (Constant)	-3.509	.846		-4.147	.000	-5.224	-1.793					
GDP	.579	.180	.599	3.224	.003	.215	.943	.518	.473	.452	.570	1.755
Urban population	-.051	.728	-.013	-.070	.944	-1.527	1.425	.296	-.012	-.010	.621	1.611
Tertiary enrollment rate	-.347	.321	-.169	-1.078	.288	-.999	.305	.086	-.177	-.151	.805	1.243

a. Dependent Variable: Recycling rate

Table 9. All models had significant ANOVA values indicating that the null hypothesis posed when performing the ANOVA (the regression equalling zero), can be rejected (Leech *et al*. 2008). This in turn, means that all the models significantly predict recycling efficiency.

Model	ANOVA Sign.
1. Recycling rate, GDP + ENV	0.002
2. Recycling rate, GDP + URB + EDU	0.006
3. Recycling rate, GDP + URB	0.003
4 Recycling rate, GDP + EDU	0.002

4.3 Assumption check

The main assumptions that the multiple regression analysis is based upon was checked using the information in Table 7 and 8 and performing scatter plots and simple linear regressions. Some deviations were found.

4.3.1 Linearity

Scatter plots and linear regressions for the linearity check between recycling rate and the predictors showed that there was good fit to a linear trendline between Recycling rate and GDP (R^2=0.40, p<<0.001) but not for the rest of the predictors (R^2<0.10). However, in spite of the poor fit, the relationship between Recycling rate and Urban population rate turned out to be significant (p<0.05). Conslusively, the assumption proved true for GDP and to some extent URB, but not for ENV and EDU.

4.3.2 Intercorrelation

In the first model using the smaller data set, there is no problem with multicollinearity. This is shown by the high Tolerance and VIF-values (Tolerance=0.998, VIF=1.002 for both predictors) in Table 3 and the lack of significant intercorrelation in the correlation matrix (Table 2).

There were significant intercorrelations between the predictors in the large data set; GDP and Urban population rate (r = 0.610, p <0.05), GDP and Education (r = 0.432, p<0.05) and between Urban population rate and Education (r = 0.337, p<0.05), see Table 7. This means that there might be a problem with multicollinearity, a fact also supported by the low Tolerance values for GDP and Urban population rate (Tolerance=0.570 and Tolerance=0.671) in Table 8. With an R^2 of 0.292 in model 2 (Table 4), multicollinearity could be a problem for the predictors GDP and Urban population rate.

4.3.3 Normally distributed errors

Scatterplots for model 1 (GDP+ENV) and 2 (GDP+URB+EDU) were performed to test if the errors were normally distributed and to see if the variances of the residuals were constant, see Figure 2 and 3. If normal distribution is the case, then the dots in the graphs should be scattered and no pattern should be seen when looking at the graph (Leech *et al.* 2008). This is not the case in either of the graphs, indicating that the errors are normally distributed and that the variances of the residuals are constant, thereby fulfilling the assumption.

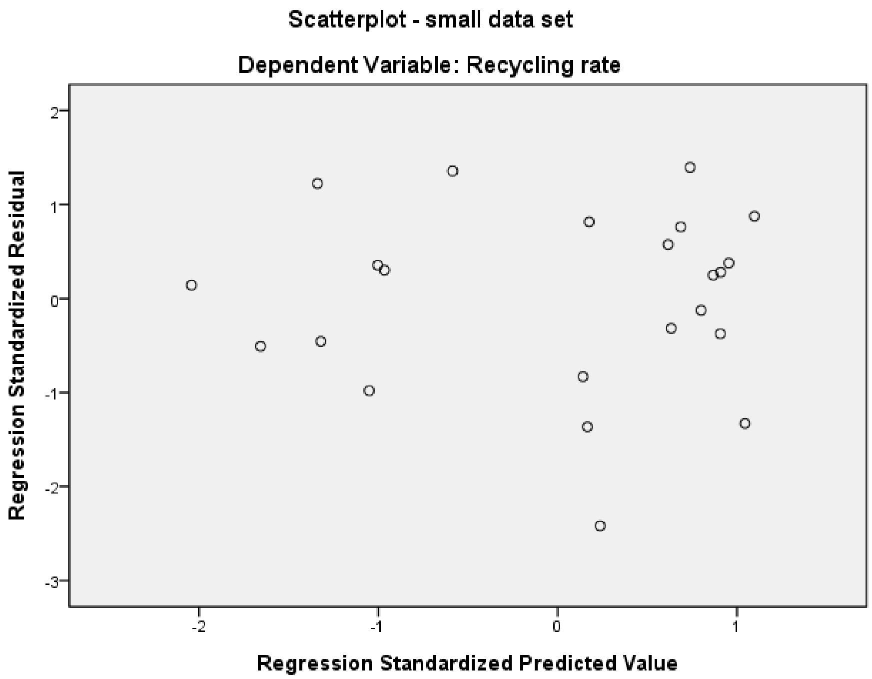

Figure 2. The scatterplot of the large dataset of model 1 (GDP+ENV) shows a fairly good scatter, This indicates that the errors are normally distributed and that the variances of the residuals are constant, thereby fulfilling the assumptions of that they should be.

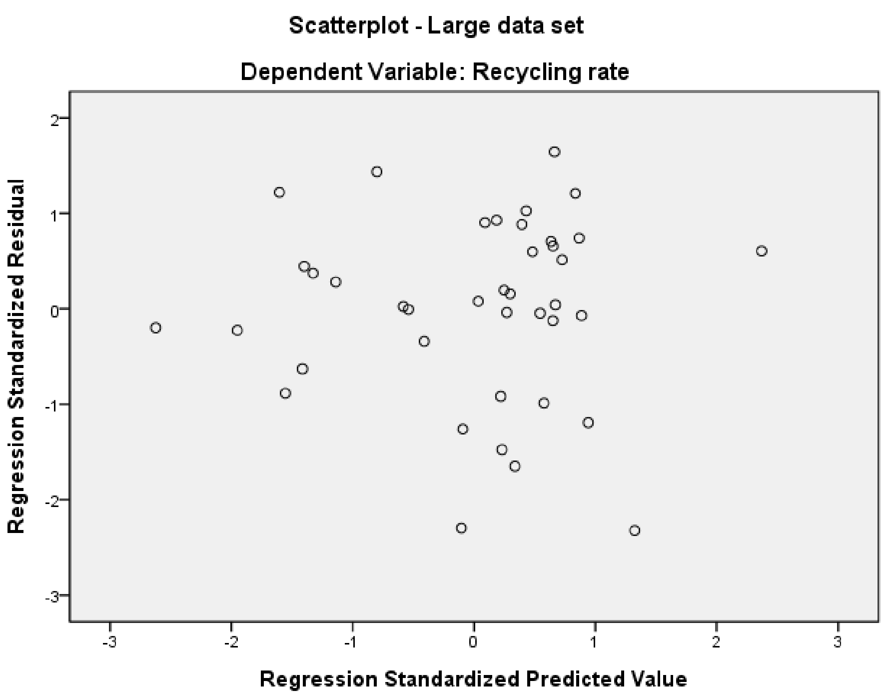

Figure 3. The scatter plot of the large dataset of model 2 (GDP+URB+EDU) shows a good scatter, indicating that the errors are normally distributed and that the variances of the residuals are constant, thereby fulfilling the assumptions of that they should be.

4.4 Further division of data

To compare the two datasets (a small one with only EU-member countries and a larger one including all countries), simple linear regression between Recycling rate and GDP was performed. The result shows a better fit for the small data set (R^2=0.378 compared to 0.276 for the larger data set), see Figure 3 and 4.

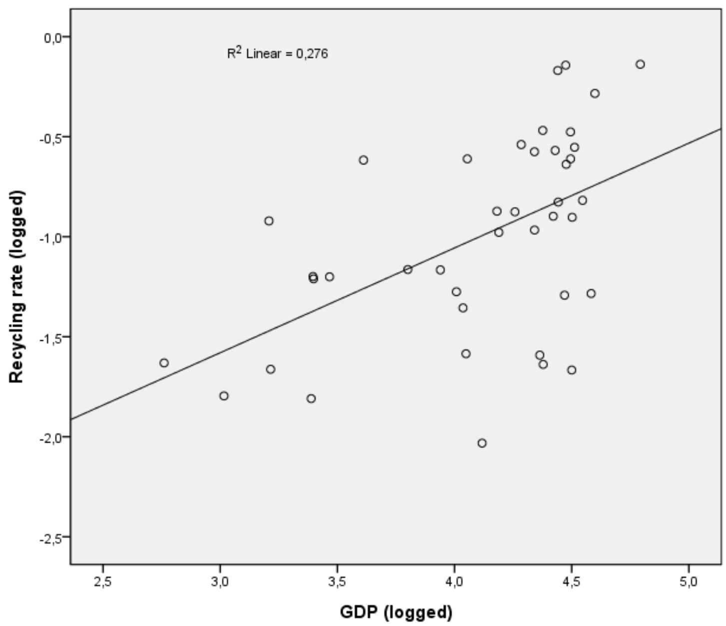

Figure 4. Scatter plot showing the relationship between Recycling rate and GDP when data from all available countries are tested. The R square-value is 0.276.

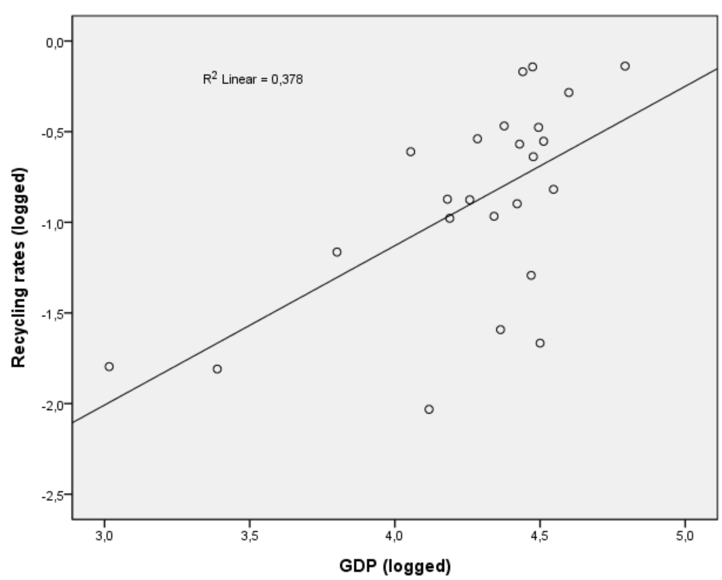

Figure 5. Scatter plot showing the relationship between Recycling rate and GDP when only data from the available EU-member countries are tested. The R square-value is 0.378.

5. Discussion/conclusion

All four models showed fairly low adjusted R square values, with the first model, testing GDP and Environmental concern as predictors, giving the best fit (adj. R^2 = 0.382). Model 4, testing GDP and Education as predictors, followed with an adjusted R square value of 0.254 and model 2 and 3 both at about 0.230. Only the first model could therefore explain the differences between recycling success of the tested countries to any reasonable extent.

Only GDP and Urban population rate did correlate significantly and positively towards recycling rate, but only GDP proved to have a significant effect when put in the models. Education, Urban population rate and Environmental concern did not correlate positively towards recycling rate when put into the models, proving the hypotheses wrong. However, correlated alone against Recycling rate, only Environmental concern did correlate negatively.

What is clear though is that GDP is a promising predictor of recycling efficiency, describing some of the variation between the countries. In all models GDP is significantly correlated towards Recycling rate and contributes significantly to the model equations, as can be seen by looking at the correlation and coefficients tables (Tables 2, 3, 7 and 8).

5.1 The small data set

Of the two predictors in the first model in the smaller data set, only GDP had a significant coefficient and is therefore the only predictor significantly contributing to the equation. This indicates that the better fit is caused by GDP rather than Environmental concern which is further supported by the fact that the partial correlation of GDP (Table 3) does not differ from the zero-order correlation (0.652 compared to 0.652). This indicates that when the effect from the predictor Environmental concern has been removed, the correlation coefficient is still the same, thereby responsible for the entire fit of the model.

Environmental concern did not correlate significantly to recycling rate in model 1. It also correlated with a slight negative trend, both when correlated alone against Recycling rate but also in the model. This means that the higher score in Environmental concern, the lesser the recycling rate, rejecting the hypothesis of Environmental concern relating positively to recycling success. I think that one part of the explanation could be that people's beliefs and their action are not always the same (mentioned in Chapter 3.1 and previously stated by Dahlén 2008). This would affect the result in that countries with respondents that scored high on the three related questions, do not contribute as much as expected to a higher recycling rate. However, a failing stringency between belief and act does not necessarily mean that a lesser concerned population is less active as compared to how they express their concern, which is why this is not a satisfactory explanation for the negative correlation. Another contributing factor could be that people in developing countries may be environmental aware and concerned but lack the structure of a recycling programme taking care of waste. This way the score of Environmental concern would be high but the recycling rates would be lower than expected.

5.2 The larger data set

In the larger data set, Urban population did correlate significantly to Recycling rate. The relationship was positive, i.e., the more people living in urban areas the more recycling. However, when put into the models, Urban population rate never achieved a significant coefficient, making it not trustworthy for predicting recycling efficiency as part of the model. This could be because of problems with multicollinearity, discussed further in Chapter 5.3.

In the larger data set, the education predictor, (Tertiary enrollment rate), however positive, did not correlate significantly to recycling efficiency. Neither did it prove to have a significant coefficient when put into the models, thereby not contributing significantly to the equation. This variable was chosen over the standardised test (PISA) due to more available data. If that was not the case, the PISA approach would be preferable because it correlated with a better fit than the other education measurements. Tertiary enrollment rate is a measure of how large proportion of the population that enters tertiary education. Nothing is said if the education is completed and nothing can be said of the quality of the education. What can be said is that probably, to enter tertiary education, a person has to pass the third level, making this the lowest level of completed education that the respondents have undertaken. This of course, could be a contributing factor to the insignificant results. Education also correlated significantly with both GDP and Urban population rate and had Tolerance-values bordering to the limit where multicollinearity becomes a problem.

5.3 Multicollinearity

In models 2, 3 and 4 there are definitely potential for problems with intercorrelation. This means that the predictors partly describe the same information and may cause difficulties when interpreting the results. When the independent variables (GDP, ENV, EDU, URB) are dependent of each other, there is a difficulty in separating the effect that the predictors have on the dependent variable (Recycling rate) from the effect they have on each other. The absence of multicollinearity of the independent variables is one of several demands that should be fulfilled to use multiple regression analysis successfully. This might prove to be a future problem for predicting recycling efficiency. If using GDP as a predictor, many other potential predictors might have to be excluded because of this intercorrelation. When the intercorrelation is strong, ($r>0.50$-0.60) then it is advisable to try to combine the intercorrelating variables into one single predictor (Leech *et al*. 2008). I think that this would be a good thing to do with the tested socio-economic predictors GDP, Urban population rate and Education (providing a better measurement and more data can be found).

5.4 A general description of a complex scenario

In this case, when trying to predict recycling efficiency, a very complex scenario is being described by a very general model. I think that a model that would be able to produce a good fit would have to include more of all those predictors mentioned in

Chapter 2.3, as was the case with the study by Schoot et al. (2011). They tested both socio-economic predictors such as social and economical conditions but also included governmental involvement and international trade legislation.
If I would have had a large enough set of data, it would make sense to divide it into smaller parts. This way you could capture the complexity of the different waste and recycling situations. One way of separating the data would be to have a group of countries with only formal WMSs and one with those that have both formal and informal systems. Many of the assumptions made when testing different predictors will become twisted when including both systems in the tests because the systems are driven by different drivers, as discussed by Wilson *et al*. (2009). The informal WMSs are driven by the value of waste as a resource and lack the advantage of governmental support. When it comes to countries with low education rate (and high unemployment rate) more people could be available for scavenging, thereby contributing to a higher recycling rate. Then on the other hand, the unofficial recycling is probably (if at all) not measured correctly because of the nature of its inofficiality. Because of these difficulties, dividing the data into smaller parts would help the correlations in the set where countries with formal WMS are tested because there are less of these discrepancies. When the larger data set were divided into one part with European countries and one including all (Chapter 4.4), a better correlation for GDP and recycling rate for the European countries were received (see Figures 4 and 5). The data from the European part had an R square value of 0.378 compared to correlating with the whole data set which gave an R square value of 0.276. The main underlying reason for this is probably that when dividing the data set like this, the mentioned differences in drivers becomes less significant, resulting in a better linear relationship.

5.5 Future studies

There are definitely more variables that would have been worth testing if the information was available. Potential predictors would be environmental regulation and politics, current second material market conditions, social context and international trade situations. Environmental regulation is a promising predictor because it could be divided into different groups depending on how they have chosen to apply current recycling regulations. Germany, Norway and Belgium for example, have special demands on how they collect and recycle their paper packaging, compared to Spain, Italy, UK and Greece that are true “minimalists” (Lindhqvist, 12/6 2011).
Socio-economic predictors such as GDP and education would have a place in a future model, provided that the latter is measured in a more representative way. A similar predictor to Environmental concern would be worth testing, perhaps measured differently, e.g. as number of environmentally certified companies instead of single respondents’ view of environmental issues.
There is also the question of whether the dependent variable could be changed to something with a better coverage of describing recycling success; recycling rates alone may be a good proxy for recycling efficiency, but in a wider term like recycling success, other measurements may be needed.
Building a better general model describing recycling success would, of course, be helped by extensive data sets with well harmonised data. When searching for data in the online

databases, there were notes in the meta data admitting to a low level of harmonisation and comments about it being a work in progress. This means that there certainly are discrepancies in how the countries define the wanted statistical information, thereby affecting the quality of the results.

This lack of harmonised data does not only apply to the data of the predictors but also to the data concerning recycling rates in general, whether produced by Tetra Pak or by other collecting organisations such as Eurostat and the OECD. However good the intentions of the part collecting the information are, they are dependent on each country's will and capability of measuring the actual rate of recycling. The aspiration towards achieving the often ambitious recycling goals of the existing regulation could also trigger the want for more positive but inaccurate numbers.

If combining all the difficulties (multicollinearity, linear relationship etc.) of using multiple regression analysis with the lack of enough, good quality data, together with the time and money that is needed, I stand critical towards the possibility of building models that predicts recycling success to a great extent.

5.6 So what does this mean for Tetra Pak?

For Tetra Pak, this means that they have one variable, GDP, which they can use when setting the recycling goals in the next three, six and nine year plans. A note of caution is advised though: GDP is only one part of the whole picture predicting recycling efficiency. If the relationship between GDP and recycling efficiency generally were positively linear, the fit of the models would have been better. However, I think that this gap of knowledge can be filled by combining the information given by GDP as a predictor with the information from the literature search on drivers and waste management development. If then their knowledge and experiences of the different markets would be added, I think that they stand a good chance of predicting the development of recycling and that they can be able to set future recycling goals that are reasonable for each market.

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