Carbon Indices and Carbon efficiency across value chains in Korea

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1. Introduction

Scientific evidence overwhelmingly shows that Climate Change exists and is caused by anthropogenic Greenhouse Gas (GHG) emissions, which will pose serious risks to ecosystems and human beings, including shortages of food supply, biodiversity loss, rising sea levels and floods (Intergovernmental Panel on Climate Change [IPCC], 2007). To mitigate these, 37 UN member countries adopted in 1997 the Kyoto protocol, which will run until 2012. Under the Protocol, Annex 1 countries (mainly European Union Countries, Russia, Ukraine, Australia, USA, Australia and Switzerland) committed to reducing their GHG emissions by five percent on average, based on 1990 levels, by 2012 (United Nations Framework Convention on Climate Change [UNFCCC], 2008).

The IPCC (2007) argues that, to keep global mean temperature rise below 2℃ relative to pre-industrial levels, global GHG emissions need to peak by 2020 and decrease by more than 50% below 1990 by 2050, although there is uncertainty whether this will suffice or what will come after Kyoto. If this is to happen, profound and deep change is required far beyond the current commitments and international endeavours will transform global markets, which in turns suggests new competition to curb carbon emissions and remain competitive for firms and nations (Hoffman, 2004). A decisive factor in this ability of societies to provide sustainable development within these carbon targets must therefore be the relative efficiency with which resources, notably carbon-emitting energies, are converted into, and used as, products.

South Korea is an Annex 2 country which, with few natural resources, has developed its economy adopting an aggressive export-oriented strategy since 1960s (Kleiner J, 2001). During this period, Korea mastered its role in various value chains as a "processor", importing raw materials and energy, processing these and exporting them. As a result, Korea became the seventh largest exporter and tenth largest importer in the world in 2010 (Ministry of Knowledge economy, 2011). Strategically, this model of development, theoretically applicable to most resource-poor and open countries, depended on its ability to consistently have positive net value-added, where the prices of exports needed to outperform factor costs. Even though South Korea's GDP per capita reached two-thirds of the average of OECD countries in 2005 (OECD, 2005), but it has the fastest-growing GHG emissions of any member state (Jones & Yoo, 2010). Even though earlier research found a very high correlation between GHG and GDP growth, caused by the growth of the energy intensive industry (Oh, Wehrmeyer, & Mulugetta, 2010), it is timely to consider the efficacy of being a "processor" with specific emphasis on heavy manufacturing.

In fact, Korea emits about ½ bn t CO2eq p.a. (9n 2008 (10.3t pp) (IEA, 2008), with over 80% of its energy imported. As a result, Korea notified the UNFCCC about its national carbon reduction goal to reduce GHG emissions by 30% below 2005 level by 2020 (UNFCCC, 2010), has passed the Low Carbon Green Growth Act (LCGG) in 2009 (Ministry of Government Legislation, 2010) and prepares legislation to introduce Emission Trading system from 2015 (Prime minister's office, 2010).

Strategically, Korea also must review whole value chains to improve economic value creation and to manage carbon emissions: In a low carbon economy, corporate value creation depends on a company's place in the value chain as well as individual company's efforts to tackle Climate Change (Carbon Trust, 2008).

However, there is no carbon index readily available for stakeholders to evaluate economic and carbon performances across value chains. This research will review existing, and develop as well as apply a new set of indices to help understand the impact of carbon on a whole value chain; to identify a bottleneck in transforming a value chain towards a low carbon system; and to compare or rank effectively firms' carbon performances within the same business sector or part of a value chain. For these indices to work across business units of the same value chain, or across different value chains, it is important to normalise carbon emissions to account for varying sizes and energy intensities of different business actors. This paper will therefore address these research objectives by discussing the questions below.

① What is the state of art in exiting carbon index across a value chain?
② What are proper carbon indices across a value chain?
③ How can the carbon indices be applied to a real value chain?

This research will mainly focus on carbon indices applicable to companies, business sectors and value chains. To start, firstly, we define a carbon index as an index or indicator to combine carbon emission data (or indicators) of an economic entity and its economic metrics (data or indicators). Secondly, we define a “value chain” as the sequential plot of the path in which value is added by the different stages, business sectors from raw material to finished product, that provide goods or services (Lysons & Farrington, 2007). Thirdly, value chain analysis is as a process of mapping and analysing the various activities involved with the production or a product.

2. Existing carbon indices

Despite its relative youth, the field of carbon indices is very active, with Hoffman & Busch’s (2008) probably seminal work. Theoretically, a firm’s carbon performance can be expressed as numerous types of carbon indices, for example, productivity and efficiency index, intensity index, percentage index (WBCSD & WRI, 2004b). However, practically, carbon intensity, expressed by the ratio of firm’s GHG emissions to its business metrics, has widely been used for comparing company carbon reduction efforts because it has more explanatory power than efficiency index in comparisons between companies (Hoffmann & Busch, 2008). However, exiting carbon indices mainly focus on the behaviour of individual companies and therefore cannot fully support information to look at a whole value chain quantitatively. As a result, the carbon indices system to diagnose a value chain needs to be developed.

To standardize the exiting carbon intensity, Hoffman and Bush (Hoffmann & Busch, 2008) suggest, on the basis of the GHG protocol, the carbon usage which consist of carbon input dimensions or carbon output dimensions as its nominators as follows:

Scope 1 covers the carbon emission sources which are owned or managed by the company; Scope 2 covers indirect carbon sources associated with purchased energy; Scope 3 accounts for further indirect GHG emissions associated with the purchased or used materials and services. As its denominator, they also suggest a choice of six business metrics: Unit of product/Turnover (sales); Total costs; Costs of goods sold; Value added; Earnings before Interest and Taxes (EBIT); and market capitalization (equity). Earlier, Olsthoorn et al (2000) have discussed their relative merits (table 1).

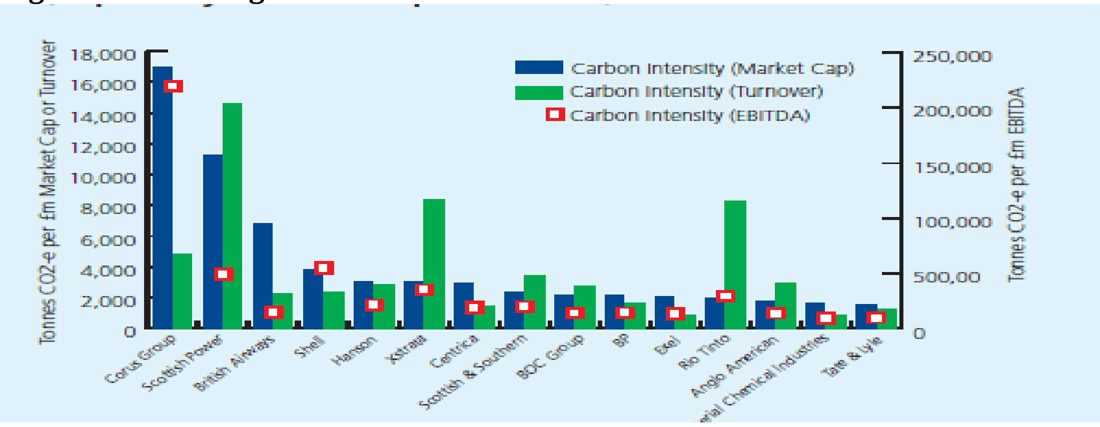
Table 1 Merits and demerits of business metrics

Denominator	Merits	Demerits
Production Output	Harmonized with comparison by one unique product output	Difficult comparison across sectors to have a variety of outputs and inputs
Turnover or sales	Simple and available	Double counting in a value chain
Value added	To reflect the contribution of business activity to the global welfare	Generally, Its definitions vary at the corporate level.
Operating profit	Available	Depend on firm's decisions outside the system boundaries
Number of employees	Another approach for business activity	Different labour intensities across sectors or countries
Total investments	Substitute for turnover or value added	Only a part of business activity

Sources: Olsthoorn et al (2000)

There is wide agreement that carbon index should be set up sectorally (Clift, 2003; Thomas, Tennant, & Rolls, 2000; Thomas et al., 2000), because each sector has its own characteristics and carbon profiles. In addition, normalised indices are sector sensitive (Thomas et al., 2000). However, it is still unknown which business metrics are suitable as denominator for different business sectors: If an individual company would select the denominator of carbon intensity arbitrarily, it would be difficult to compare corporate carbon performances. Henderson and Trucost (2005) show that the carbon intensities which use different business metrics produce different rankings as seen in Figure 1, which opens the possibility that companies may pick data collection and denominator alternatives based on political or strategic reasons. It also allows a more fragmented view of value chains to emerge, so that a string argument for a consistent use of nominators and denominators across, but not necessarily between, value chains can be made.

Figure 1 – Rankings of carbon Intensities



Source: Henerson & Trucost (2005)

3. A proposal for carbon indices across value chains

3-1. Carbon indices to diagnose a value chain

Clift (2003) analyzes the evolution of sustainability indicators across supply chains and he suggests the use of very generic indicators across life cycles of products using his Overall Business Impact Assessment (OBIA):

$$\varnothing_{i,j} = \frac{[\text{Impact in category i/Value of business j}]}{[\text{Total anthropogenic contribution to impact category i/Total global economic activity}]}$$

where $\varnothing_{i,j}$ is OBIA parameter of business or product group i in environmental impact category j (Taylor & Postlethwaite 1996 cited in Clift 2003). This OBIA parameter was used by Unilever to identify which business sectors, areas and product groups should be focused for environmental improvements (Clift, 2003). Value added is recommended for economic dimension of this parameter because Value added means the contribution of business to GDP which indicates welfare of a country (Clift & Wright, 2000).

Jackson & Clift (1998), Clift & Wright (2000) and Clift (2003) extend this OBIA approach to analyze the environmental and economic performance of value chain or economic entities, a “Hybrid Approach” because of its link of environmental and economic dimensions (Dahlström, He, Davis, & Clift, 2004). The ratio of cumulative environmental impact and cumulative economic value along a value chain typically show a convex segmented curve (Clift & Wright, 2000). This convexity shows that actors located earlier in a value chain often show higher pollution with lower economic benefit, and vice versa (Clift, 2003; Clift & Wright, 2000). When this approach is applied to pollutant emissions for different industrial sectors from the form [Environmental impact of sector]/[Value added of sector], the convexity can also be shown (Clift & Wright, 2000).

Apart from this being a powerful argument for recycling and reuse to avoid the inefficiencies of (low economic value for high environmental impact) raw materials production, Clift (2003) argues that convexity is an indicator of inequity, because if the value chain has more equitable distribution of environmental impact and economic benefits, its curve would appear to be straighter. Convexity can supply stakeholder information to diagnose carbon performance of a value chain. Applied to the economic development model of Korea, this suggests that Korea's policy of a "raw materials processor" avoids most inefficiencies in the raw materials stage, but there may be strategic decisions to be made as part of its environmental policy to focus on more efficient stages further down certain value chains.

Carbon inequity across a value chain can be defined as inequitable distribution of carbon emission and economic benefits. It increases the steeper the convexity of the OBIA curve. It also means that the burden of carbon reduction converges stronger on sector with comparatively higher carbon emissions and less economic benefit. This is to compound with greater energy prices, greater energy demand in a given value chain, tougher regulation or taxation on carbon emissions.

As a result, convexity of carbon equity can be a good indicator to diagnose the carbon performance of a value chain. This is so far expressed only as a graph which makes it difficult to analyse, especially given the many and different value chains. Therefore, we suggest a Carbon Equity Index of Value chain (CEIV) index as follows:

$$CEIV = \frac{MaC}{MiC}$$

Where *MaC* means the maximum value of the Carbon Impact Assessment Index (CIAI) and *MiC* represents the minimum value of CIAI in the same value chain. CIAI, which is an OBIA parameter, express the carbon impact of a business within a value chain as follows:

$$CIAI = \frac{C / V}{TC / TV},$$

in which C is the carbon emission of a business, V is its value added, TC is total carbon emission of a value chain and TV is total carbon emission of the same value chain. If the carbon impact and value added of each stage (business sector) of a value chain is distributed more equitable along that chain, its CEIV value is expected to be closer to one. Adversely, if that carbon impact and value added is allocated more un-equitable, its CEIV increase in proportion to this unfairness.

There are other indices of inequality in use, notably the Gini Coefficient, measuring inequality of income distribution; precisely, the proportion of areas on the Lorenz curve. That curve plots income generated across all income brackets, and the greater the divergence of the Lorenz Curve from the theoretical equal, the greater the Gini Coefficient. Compared to CIAI, it is based on less simple mathematics and does not allow an easy assessment of the role of different denominators, which is why the CIAI was not modelled on the Gini Coefficient.

To calculate CEIV and CIAI exactly, this report introduces the term ‘added carbon’ as the carbon emission to be matched up with value added. Value added also reflects the contribution of a business sector to the Gross Domestic Product (GDP) (Azapagic & Perdan, 2000). The direct carbon emissions of a business sector are directly related with the value added which this sector creates. The indirect carbon emissions of this sector are attributed to the value added of those business sectors which emit these carbon emissions directly. For example, the carbon emissions of the purchased electricity are allocated and attributed to the value added of the utility which produce the electricity. These CEIV and CIAI need to be applied by using Value added as economic metrics and added carbon (Scope 1) as carbon performance.

3-2. How to determine the denominator of Carbon Intensity

As argued, the carbon indices should be sector specific, here classified using the International Standard Industrial Classification (ISIC) of the UN to enhance national and international comparison.

Secondly, the boundaries of carbon emissions need to be delineated: According to the Polluter Pays Principle, Scope 1 falls under a firm's direct responsibility and Scope 2 or Scope 3 are indirect (DEFRA & Trucost, 2006). Only when companies to purchase electricity have a specific duty to improve its energy efficiency or firms can show that their reduction of direct carbon emissions is not at the expense of increased emissions elsewhere, for example, upstream carbon, Scope 2 or Scope 3 needs to be included (DEFRA & Trucost, 2006).

Generally, Carbon intensity can be expressed as the ratio of carbon emissions (numerator) and a business metric (denominator):

$$CI = \frac{C}{B}$$

Different denominators may have meanings and applications to different objective audiences (Thomas et al., 2000). The carbon intensity in the above equation assumes a proportional, linear, relationship between carbon emissions and business metrics. It is expected that the business metrics which have most significant linear relationship or highest correlation with carbon emissions may predict or explain the carbon emissions significantly. This business metrics may be most appropriate denominator because this can produce the CI to have the least variability in the candidate business metrics. As a result, the suitable denominator can be decided by correlation analysis and multiple regression analysis.

4. Methodology

We collected data from several Korean pulp and paper value chains (Figure 2). This sector was selected because it is relatively easy to identify clearly the value chain as the products are relatively simple; there are not too many companies involved; and the value chains are relatively short with few intermediate products. This can make it easier to link the selected business actors. It is hoped that these value chains show a more general pattern applicable other business sectors (Clift & Wright, 2000).

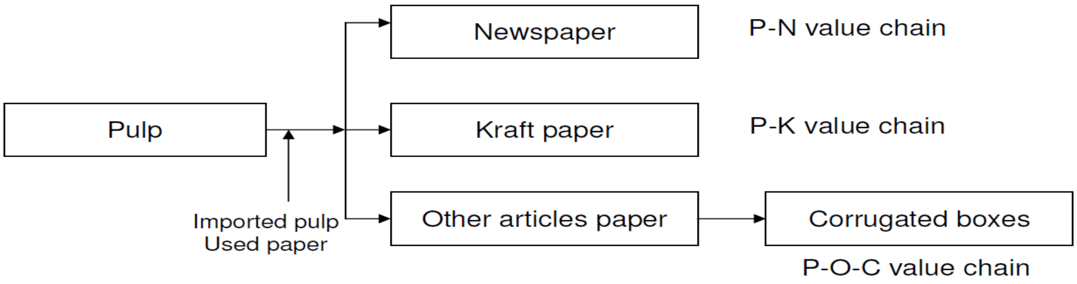


Figure 2 the selected value chains in pulp and paper sector

In the Pulp sector, one Korean company manufactures mainly chemical pulp by processing imported wood chip; another company produces mechanical pulp mainly used for newspapers. The newspaper sector uses used paper as main raw material and a small quantity of pulp as additional feedstock to manufacture newspaper. Figure 3 shows that the newspaper sector and the pulp sector construct the Pulp and Newspaper (P-N) value chain; the Kraft paper sector makes the packaging paper from pulp in the Pulp and Kraft (P-K) value chain. The length of the value chains is generally very short, but there is no logical reason why indices across longer value chains necessarily perform differently.

The pulp sector, the Other Articles Paper sector and the Corrugated Box sector compose the Pulp, Other articles and Corrugated Box (P-O-C) value chain. The companies within the Other Articles Paper sector mainly use used paper as raw material and, less so, pulp. The Corrugated Box sector then puts the parties of Other Articles paper sector together with the glue sector The number of companies in the chosen business sectors, components of the value chains, are stated in Table 2.

Table 2 The number of the companies in sub sector of the selected value chain

Year	Pulp	Newspaper	Kraft paper	Other Articles paper	Corrugated Box
2002			4	6	
2003	2	3	4	6	
2004	2	3	4	7	
2005	2	3	4	10	2
2006	2	3	3	10	2
2007	2	3	3	10	

The data included main raw material usage, main product and fuel usage and was collected directly from the companies in these 5 sub-sectors. The companies have to record, keep and report this data to the local government and the National Air Pollutants Emission system (NAPE) under the Air Environmental Conservation Law (ACL) in the ROK (Ministry of Government Legislation, 2007b). Data quality is high as the data is reviewed by the local government and the NIES annually, including factory inspections (NIES, 2009).

The industrial GHG emissions cover mainly stationary and mobile combustion; process and fugitive emissions (WBCSD & WRI, 2004a). Furthermore, the manufacturing processes of the selected companies do not cover the main industrial process and fugitive emission sources in the IPCC guidelines (IPCC, 2006). As a result, we estimated Scope 1 carbon emissions from the reported fuel usage and converted this into GHG emissions:

$$\text{Total GHG emissions (Kg } CO_2\text{)} = \sum_{fuel} A + 21 \times \sum_{fuel} B + 310 \times \sum_{fuel} C$$

Where,

A(CO_2 Emission amount of fuel) = Fuel Usage amount (Kg) × Caloric value of fuel (MJ/Kg))× Emission factor (Kg C/GJ) × 44/12 (kg Cow /Kg C) × 10^{-3};

B(CH_4 Emission amount of fuel) = Fuel Usage amount (Kg) × Caloric value of fuel (MJ/Kg))× Emission factor(Kg/TJ) × 10^{-6};

C(N_2O Emission amount of fuel) = Fuel Usage amount (Kg) × Caloric value of fuel (MJ/Kg))× Emission factor(Kg/TJ) × 10^{-6}.

This is the standard method of the Korean government (KEITI, 2010), with calorific values and emission factors in Table 3.

Table 3 emission factors and caloric value for estimation of the GHG emissions

Fuel	Caloric value[1] (MJ/Kg)	CO_2 Emission factor[2] (Kg /GJ)	CH_4 Emission factor(Kg/TJ)	N_2O Emission factor(Kg/TJ)
Anthracite Coal	19.5	26.8	10	1.4
Bituminous Coal	28..3	25.8	10	1.4
B-C oil	41.4	21.1		
LNG	54.5	20	1	0.1

Source: (KEITI, 2010)

[1] The number announced by the article 5 of the ministerial decree of the energy basic law.

[2] IPCC's emission factors converted by 41,868 TJ/106 toe

This report mainly estimates the emissions of CO_2, CH_4 and N_2O because IPCC recommends the estimation of these 3 pollutants at stationary combustion. However, this report does not estimate the CH_4 and N_2O emissions of the B-C oil, because the CH_4 and N_2O emission factors of the B-C oil are not provided yet by IPCC.

The Korean companies must publish core business data (Corporate External Auditing Law (CEAL), (Ministry of Government Legislation, 2007a) with the Korean Information Service Inc (KIS) collecting this verified and audited data. We gathered from KIS: turnover, value added, EBIT (profit), operating profit and the number of employees for all companies in all value chains.

This report will use multiple regression analysis and correlation analysis to select the most appropriate denominator of carbon intensity index, followed by Pearson's coefficient of correlations between the dependent variable (GHG emissions) and independent variables (business metrics) (Anderson, Seeney, & Williams, 2005). The closer the Pearson's correlation coefficient of two variables is to ±1, the stronger their linear relationship is (Black, 1999). The rationale behind this approach is that the business indicator that shows least variability in CI across all companies within the given value chain is likely to be the most suitable to act as a denominator. Multicollinearity is a potentially significant problem, where two or more independent variables are highly correlated to one another, which reduce the quality of the regression model (Anderson et al., 2005). One of the practical ways which can detect multicollinearity is to determine the variance inflation factor (VIF) for each independent variable:

$$VIF(x_j) = \frac{1}{1 - R_j^2}$$

Where R_j^2 is the coefficient of determination obtained when x_j is regressed on all remaining independent variables (Anderson et al., 2005). This research excludes the variables which their VIF value are more than ten, because VIF values of ten or more are regard as problematic (Anderson et al., 2005).

In a regression analysis of time series, the assumption that the errors are independent from one another may be violated, which may cause autocorrelation, which in turn reduces the usefulness of the model (Anderson et al., 2005). To check autocorrelation or serial correlation, the Durbin Watson test is generally used:

$$d = \frac{\sum_{t=2}^{n}(e_t - e_{t-1})^2}{\sum_{t=1}^{n} e_t^2},$$

where e_t represents the observed error term (i.e., residuals) (Anderson et al., 2005). The d value ranges from zero to four, with a value of two indicating that no autocorrelation is present (Anderson et al., 2005). Using d value and the Savin & White table (Savin & White, 1977), we will test the presence of autocorrelation.

There is a further problem possible, namely that the low number of cases may interfere with the validity of the results. Overall, the date for these value chains amount to 95 company years, covering 2002-2007. The approach has been replicated with other sectors of the Korean economy where larger datasets were available, and thus with better significance values. Whilst this seems to be a potential problem, no evidence was found that this is an actual obstacle.

5. Results

This section presents the results of the analysis of the 5 pulp and paper value chains using CEIV and CIAI. We will also review the selection of a suitable denominator from the Other Articles paper sector and discuss the result to select the proper CI within this sector.

5-1. Value chain diagnosis by CIAI and CEIV

The CEIV values of the P-N value chains and the CIAI values of its sectors are presented in Table 4 and Figure 3, covering 2003 to 2007. The CIAI values of the Pulp sector are measured from 0.90 to 1.04 and the CIAI values of the Newspaper sector are calculated from 0.95 to 1.16. These values mean that both of these sectors may have similar carbon impact with similar economic benefit. Despite fluctuations, these two sectors may show carbon performance at about average market level because these values are close to one (Clift, 2003; Clift & Wright, 2000). It also seems that there is no business sector that acts as a major barrier toward a low carbon economy.

The CEIV values of the P-N value chain are relatively stable from 1.07 to 1.29. This CEIV values in 2005 and 2006 are high level. Noticeably, the change of value added in the pulp sector caused the sharp change of CEIV from 2005 to 2006. With very little convexity in the P-N value chain straight, theoretically, it is expected that the CEIV of this value chain is close to one, with the actual values matching this prediction. This means that the CEIV values can express carbon equity distribution along a value chain. Through CEIV value, it is possible to diagnose that this value chain may have comparatively high sustainability in a low carbon economy. From this, it can be known that CEIV carbon index can measure adequately the changes across time related with the carbon performance and business metrics.

Table 4 CEIV of P-N value chain and CIAI values of its business sectors

Year	Pulp CIAI	Newspaper CIAI	CEIV
2003	1.04	0.95	1.09
2004	1.03	0.96	1.07
2005	1.11	0.88	1.26
2006	0.90	1.16	1.29
2007	0.96	1.05	1.09

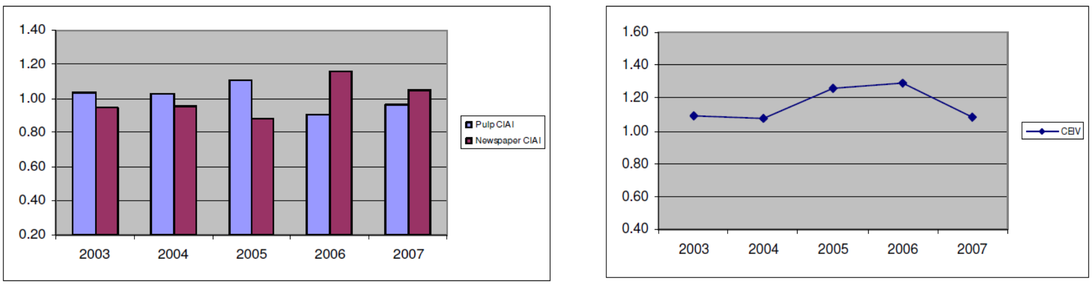


Figure 3 CIAI values of each business sector of the P-P value chain and its CEIV value

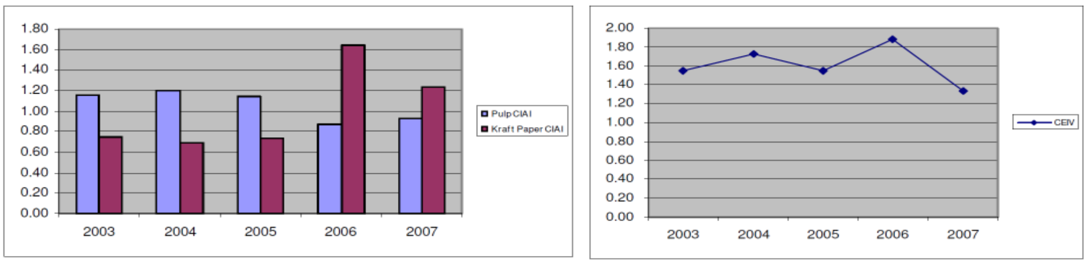
Table 5 and Figure 4 show the CEIV values of the P-K value chain and CIAI values of its two sectors during the same time as the above value chain. The CIAI values of the pulp sector are assessed from 0.87 to 1.20 and the CIAI values of the Kraft paper sector are computed from 0.69 to 1.64. In 2004, the Kraft paper sector shows the best carbon intensity in 2004, because its corresponding CIAI is the smallest value in this example. To consider that the CIAI values of these two sectors are close to one, carbon performances of these sectors may be the average market level. It is also expected that these two sectors may not work as an obstacle in transforming it a low carbon value chain. Either way, the CIAI value can express quantitatively changes in the relationship between carbon performance and business metrics.

The CEIV values of this P-K value chain are estimated from 1.34 to 1.88. The CEIV values here are considerably higher level than in the P-N value chain. This can indicate that the distribution of carbon impact and economic benefits along the P-K value chain may be relatively uneven compared to the P-N value chain. This means that, in a low carbon economy, the P-K value chain may be less sustainable than the P-N value chain.

Table 5 CEIV of P-K value chain and CIAI values of its business sectors

Year	Pulp CIAI	Kraft Paper CIAI	CEIV
2003	1.15	0.74	1.55
2004	1.20	0.69	1.73
2005	1.14	0.74	1.55
2006	0.87	1.64	1.88
2007	0.92	1.23	1.34

Figure 4 CIAI values of each business sector of the P-K value chain and its CEIV value



The CEIV values of the P-O-C value chain and the CIAI values of its sectors are shown from 2005 to 2006 in Table 6 and Figure 5. The CIAI values of the Pulp sector are calculated from 0.93 to 1.22. Those of the Other Articles paper sector range from 0.86 to 1.09. The Corrugated Box sector shows the relatively low level of the CIAI values from 0.29 to 0.49 compared to the above two other sectors. Generally, the raw material sectors show high environmental impacts with low economic benefit, and the assembly sectors show relatively low environmental impacts with high economic value (Clift & Wright, 2000; Clift, 2003). The Pulp sector, manufacturing pulp form wood chip and the Other Articles Paper sector, producing parts of corrugated boxes mainly from used paper, and thus can be included into raw material sector. It is expected that the CIAI values of raw material sector, the pulp sector and the other articles sector, are at comparatively high level and the CIAI values of the assembly sector, the corrugated boxes sector, are relatively smaller. The estimated CIAI values, high values in the Pulp and the Other Articles Paper sector and low values in the Corrugated Box sector may meet this expectation. As a result, the calculated CIAI values can express this position of a value chain.

The CEIV values of the P-O-C value chain are estimated from 4.25 i to 2.56, which are relatively high level compared to the P-N value chain and the P-K value chain. The P-O-C value chain is expected to show a typically strong convex segmented curve in the ratio of cumulative carbon impact and cumulative value added along a value chain because this value chain consist of raw material sector and assembly sector (Clift, 2003; Clift & Wright, 2000). The above measured CEIV values of this value chain can meet this expectation. As a result, it can be conclude that, through the CEIV, it is possible to diagnose carbon equity of a value chain in a low carbon economy.

Table 6 CEIV of P-O-C value chain and CIAI values of its business sectors

Year	Pulp CIAI	Other articles paper	Corrugated Box	CEIV
2005	1.22	0.86	0.29	4.25
2006	0.93	1.09	0.42	2.56

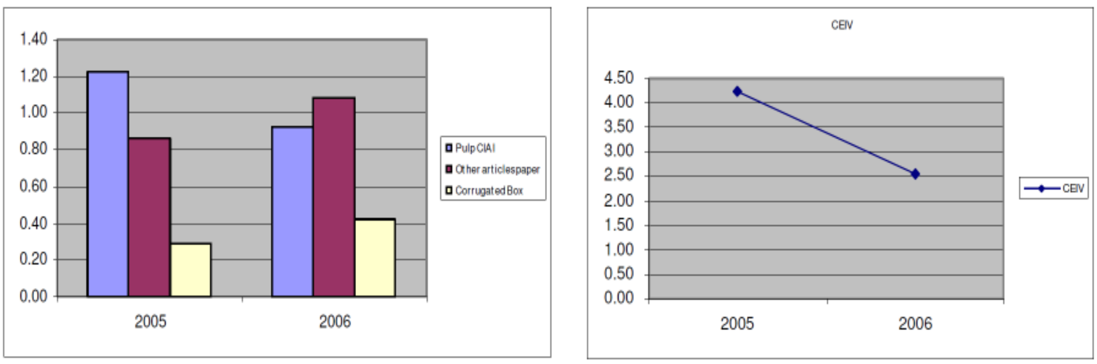


Figure 5 CIAI values of each business sector of the P-O-C value chain and its CEIV value

5-2. Selecting Denominators for Carbon Indices

This chapter will present the results of the efforts to select the denominator to rank carbon intensity in the Other Articles Paper sector. The carbon emission date and the five business metrics of the companies of this sector (Table 2) will be used.

Table 7 gives an overview of the Pearson's coefficient of the correlation between the five business metrics and carbon emission data. Three correlations, between carbon emissions and Turnover, carbon emissions and value added, and carbon emissions and employee numbers, are significant at the 0.01 level.

Table 7 Pearson's correlation coefficients between variables in Other Articles sector

Correlations

		turnover	valueadded	operatingprofit	profit	employee	carbonemission
turnover	Pearson Correlation	1	.800**	.598**	.173	.832**	.720**
	Sig. (2-tailed)		.000	.000	.240	.000	.000
	N	49	48	49	48	49	49
valueadded	Pearson Correlation	.800**	1	.723**	.402**	.632**	.427**
	Sig. (2-tailed)	.000		.000	.005	.000	.002
	N	48	48	48	47	48	48
operatingprofit	Pearson Correlation	.598**	.723**	1	.791**	.337*	.141
	Sig. (2-tailed)	.000	.000		.000	.018	.333
	N	49	48	49	48	49	49
profit	Pearson Correlation	.173	.402**	.791**	1	-.061	-.223
	Sig. (2-tailed)	.240	.005	.000		.679	.127
	N	48	47	48	48	48	48
employee	Pearson Correlation	.832**	.632**	.337*	-.061	1	.843**
	Sig. (2-tailed)	.000	.000	.018	.679		.000
	N	49	48	49	48	49	49
carbonemission	Pearson Correlation	.720**	.427**	.141	-.223	.843**	1
	Sig. (2-tailed)	.000	.002	.333	.127	.000	
	N	49	48	49	48	49	49

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

The three independent variables are correlated to one another as seen at table-8. As argued, collinearity is a possible problem in building multiple regression models, so that VIF values are calculated to check for this. It was found that the collinearity is, if any, not severe, because the VIF values are sufficiently small.

Table 8 VIF values of the business metrics

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations			Collinearity Statistics	
		B	Std. Error	Beta			Zero-order	Partial	Part	Tolerance	VIF
1	(Constant)	-311.371	4084.359		-.076	.940					
	employee	279.046	51.310	.763	5.438	.000	.839	.634	.417	.299	3.342
	turnover	.166	.090	.335	1.849	.071	.714	.268	.142	.179	5.587
	valueadded	-.357	.143	-.323	-2.506	.016	.427	-.353	-.192	.355	2.815

a. Dependent Variable: carbonemission

The regression model suggested at Tables 9 and 10 was found to be the best model, with the largest Adjusted R^2, 0.722, $p<0.05$. The adjusted R^2 can measure the success of the regression model most usefully (Brace, Kemp, & Snelger, 2006)

Table 9 the summary of the selected regression model

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.839[a]	.704	.697	13862.892	
2	.857[b]	.734	.722	13282.212	1.429

a. Predictors: (Constant), Numberofemployee
b. Predictors: (Constant), Numberofemployee, EBIT
c. Dependent Variable: Carbonemission

Table 10 the coefficients of the selected regression model

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Collinearity Statistics	
		B	Std. Error	Beta			Tolerance	VIF
1	(Constant)	2157.178	4078.626		.529	.599		
	Numberofemployee	306.904	29.373	.839	10.449	.000	1.000	1.000
2	(Constant)	2495.183	3910.642		.638	.527		
	Numberofemployee	302.291	28.216	.826	10.713	.000	.995	1.005
	EBIT	-.630	.279	-.174	-2.261	.029	.995	1.005

a. Dependent Variable: Carbonemission

This model was found not have autocorrelation errors: The Durbin Watson test statistic value (d) of the above regression model is 1.429. In the Savin & White table, the lower bound of this model is 1.201 and its upper bound is 1.424 (Savin & White, 1977). The null hypothesis of no autocorrelation errors can thus not be rejected (Anderson et al., 2005).

From this selected multiple regression model, it can be understood that the number of employees may show least variability with Scope 1 carbon emissions. As a result, in the Other Articles paper sector, "number of employees" was selected as denominator for carbon intensity to then rank or compare the firms' carbon performances.

These carbon intensity ratios were produced and show comparatively stable rank-orders from 2002 to 2007 (Figure 7). This can support the view that the ranking of the corporate carbon performances was stable during this time. This, in turn, is supported by historical evidence in the sector, where no additional environmental regulation, no specific carbon-related initiatives and no substantial technology change was noted, neither for the sub-sector as a whole nor for individual companies. However, the carbon intensities that were calculated using other business variables show comparatively much less stable rank-orders (Figure 8&9). As a result, we concluded that the carbon intensity using "employee numbers" as denominator is better at ranking companies in the Other Articles Paper sector

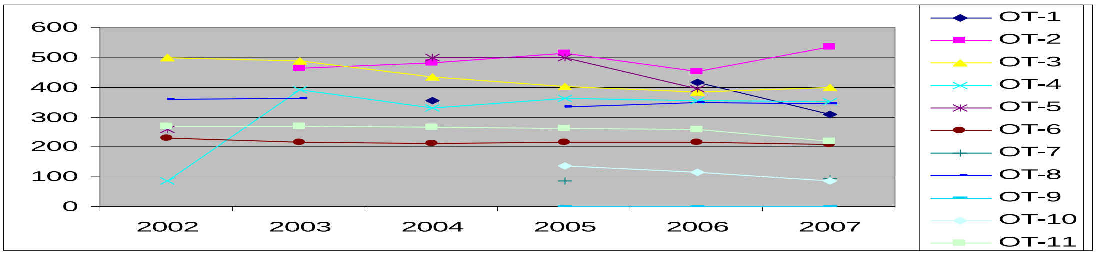


Figure 7 Ranking of Carbon intensity (Scope1 / Number of Employee)

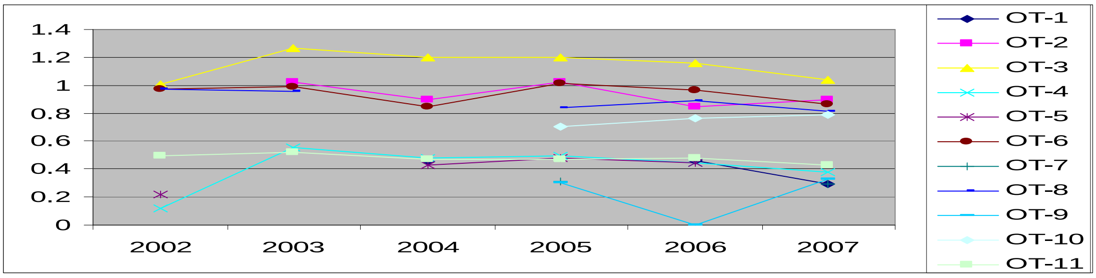


Figure 8 Ranking of Carbon intensity (Scope1 / turnover)

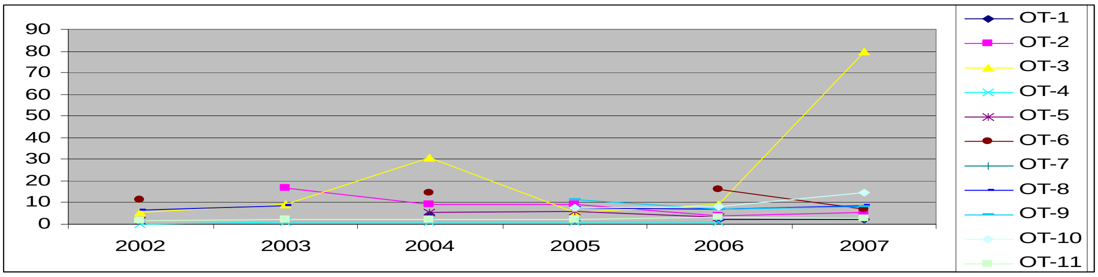


Figure 9 Ranking of Carbon intensity (Scope 1/ Value added)

6. Conclusions

Global policies to mitigate climate change and natural resource constraints will transform global value chains towards a low carbon economy (Business for Social Responsibility, 2009). Even though South Korea's development history has been characterised as a "processor", the analysis of Carbon Intensity across value chains suggests that South Korea can actively improve its favourable position by strategies to increase economic value derived from production at given carbon emissions across value chains.

To improve, stakeholders can use the proposed carbon index to analyse different value chains to create more economic benefits at given carbon emissions, or to reduce carbon emissions at given economic output. However, exiting carbon indices do not provide sufficient information as they mainly focus on individual companies.

We suggest both, CEIV and CIAI as the carbon index to diagnose carbon performance of a value chain, and a new approach to decide the carbon index denominator to effectively rank firms' carbon performance in a given value chain. The CEIV is designed to express the distribution of carbon impacts and economic benefits across a value chain - called carbon inequity - quantitatively. This carbon equity is one of the main factors to decide its sustainability in a low carbon economy, because the more carbon inequity of a value chain increases, the more attention to reduce carbon will be focussed on this sector with much carbon impact and less economic value. The CIAI can inform bottlenecks in transforming a value chain towards low carbon system. In literature, Carbon Intensity is widely used to compare or rank firms' carbon performances. This report suggests the correlation analysis and multiple regression analysis to decide the proper denominator by a sector specific approach. However, sustainability, of course, covers wider issues than the CIAI measures, which primarily inform sustainability considerations via its resource efficiency evaluation.

This report applied the CEIV and CIAI carbon indices to three value chains, namely P-N value chain, P-K value chain and P-O-C value chain. CEIV can measure carbon inequity properly across time. The CEIV of the P-N value chain has the best carbon equity with values around one. By contrast, the P-O-C value chain has the lowest carbon equity with much larger estimates. The CIAI values of the P-O-C value chain support the general pattern of value chain as Clift said (Clift, 2003; Clift & Wright, 2000). The CIAI values of raw material sector, the pulp sector and the other articles sector, are at comparatively high level, near to one and the CIAI values of the assembly sector, the corrugated boxes sector, showed relatively small values.

This report applied the correlation analysis and multiple regression analysis to decide the proper denominator which can be properly matched to Scope 1 carbon emissions, the nominator of the ranking carbon intensity within the Other Articles paper sector.

“Number of employees” was selected using the described method and it shows that the carbon intensity index with this denominator shows better ranking in the Other Articles value chain than other denominators.

This research encountered several problems in developing a new carbon index system across value chain. Firstly, it is difficult to acquire accurate and full data because most of the essential data is confidential or, in the case of carbon emissions, data quality may be very uneven, which made us focus on fuel and electricity usage data.
Secondly, it is not easy to classify clearly the analyzed companies into sub-sectors because most of companies produce several kinds of products for different sectors. Inevitably, this research applied only the Scope 1 from this emission source on the assumption that these may be the main emissions of the analysed companies. The CEIV index is a new index which has been applied to small number of value chains here.

However, we suggest a new carbon index system to have a look at a value chain entirely. The logic behind it, namely to use the ratio of carbon emissions per value-added to inform industrial policy is well established (Clift & Jackson, (1998), Clift & Wright, (2000) and Clift (2003). It also makes intrinsic sense as it can help Korea’s government to develop policies to support its drive towards a low carbon economy effectively.

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