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Applying Grey Relational Analysis to Find Interactions between Manufacturing and Logistics Industries in Taiwan

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Abstract

The development of manufacturing and logistics industries is an important economic index and plays a significant role in developed countries. In Taiwan, both manufacturing and logistics industries have continuously developed in the past few decades, and their development has become interdependent. For instance, the transportation demand of manufacturing industries has an impact on the development of logistics industries. To effectively foster the development of these two sectors in Taiwan, it is necessary to identify the relationships between them. Grey relational analysis with an entropy calculation reveals some interesting findings. (1) The main manufacturing factor driving the logistics industry is employment compensation. (2) The main logistics factor driving the manufacturing sector is length of roads. (3) A fairly strong interaction exists between logistics and manufacturing industries.

JEL classification numbers: C33, L60, L90
Keywords: logistics, manufacturing, multiple criteria decision making, grey relational analysis, entropy.

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1 Introduction

All the historical examples of successful economic development and catch-up since 1870 have been associated with industrialization (Szirmai, 2012). The development of manufacturing industry is an important index in measuring the overall strength of a country (Szirmai and Verspagen, 2015). The manufacturing industry in Taiwan has undergone extensive development in recent decades. At present, Taiwanese manufacturing includes metal, nuclear power, electronics, information, chemical, and livelihood sectors, with advanced technology and strong production capacity. In addition, Taiwan has tens of thousands of product categories and an efficient supply–production–sales chain that flows from upstream to downstream industries (Chiang and Hwang, 2007). In particular, Taiwan has become an important global production base for high-tech products (Chan, Chang, and Hsu, 2004). Figure 1 shows the contribution of manufacturing industry to GDP in Taiwan. The total value of manufacturing output accounted for 26.41–29.56 % of GDP during 2005–2014. Therefore, manufacturing has become a major factor in economic growth (Fagerberg and Verspagen, 2002).

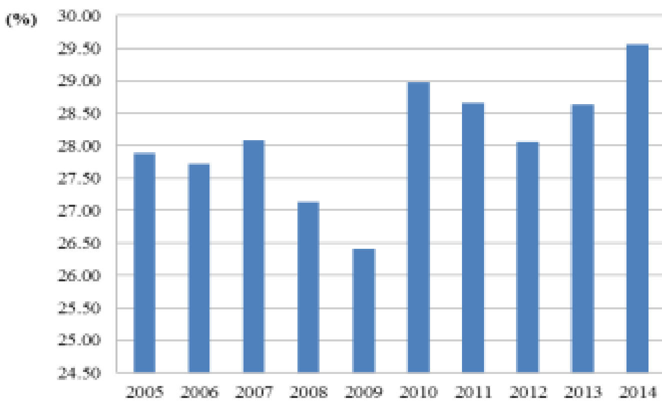

Figure 1: Contribution of manufacturing industry in GDP of Taiwan

Logistics can reduce inventory, accelerate revenue turnover, and improve the competitiveness of enterprises (Sandberg and Abrahamsson, 2011). As the third profits source, logistics has been the focus of increasing attention (Marasco, 2008). As an important part of producer services, the logistics industry is highly dependent on the manufacturing sector (Chan, 2005; Voordijk, 1999). Manufacturing is the main source of logistics demand (Mortensen and Lemoine, 2008), and progress in manufacturing has greatly helped and promoted the logistics sector (Hertz and Alfredsson, 2003). Conversely, the development level of the logistics industry is directly related to the efficiency of manufacturers and the benefits they experience (Choi, Wallace, and Wang, 2016). An increasing number of manufacturers are realizing the importance of logistics, and outsource non-core business activities such as delivery and distribution to third-party logistics enterprises (3PLs) (Li et al., 2012). However, transmission of logistics information among manufacturers and 3PLs is not very smooth, which has seriously affected the efficiency of enterprises (Shi et al., 2016). Therefore, interactive development of logistics and manufacturing industries is essential (Hwang, Chen, and Lin, 2016) and is key to improving core competitiveness and promoting upgrading among manufacturing firms (Shang and Marlow, 2005).

Previous studies have investigated the interactive development of manufacturing and logistics industries. Wang and Chen (2012) believed that the interactive development of two industries is aimed at symbiotic development, with reciprocity and complementarity principles. Good interaction between two industries can contribute to reducing operating costs, encouraging manufacturing productivity, and improving core manufacturing competitiveness while simultaneously improving logistics service levels (Peng and Feng, 2010). Therefore, the goal of interaction is to achieve a win–win situation (Wang, 2014).

Grey relational analysis (GRA) as proposed by Deng (1982) can be used to effectively measure the degree of relationships between given data sequences (Liu and Lin, 2006; Wen, 2004). Therefore, the relationships among index factors for the development of manufacturing and logistics industries can be measured using GRA. The dominant factors affecting interactive development between manufacturing and logistics industries can thus be determined. GRA has been widely applied to various fields (Wei, 2011; Li et al., 2015; Hu, 2015, 2016; Huang and Wang, 2016; Wu et al., 2016).

2 Methodology

We use entropy to determine the relative importance of each evaluation factor and then apply GRA to identify dominant factors affecting interactive development between manufacturing and logistics industries.

2.1 Entropy

The theory of entropy was first proposed by Clausius in 1865, and is now widely used in many fields, such as economy, management, energy, and mathematics. Machado (2016) addressed the concept of negative probability and its impact on entropy. Stosic et al. (2016) used entropy to explore the foreign exchange rate during financial crises. Xu, Shang, and Huang (2016) proposed a modified method of generalized sample entropy as a new measure to assess the complexity of the stock market. Entropy is typically used to calculate weights for factors, especially when combined with GRA (Hsu and Chien, 2008; Hsu and Kuo, 2007; Kuo, Yang, and Huang, 2008; Rajesh, Rajakarunakaran, and Sudhkarapandian, 2014; Shuai and Wu, 2011; Sun, 2014; Verma, Sarangi, and Kolekar, 2014; Wu, 2012).

2.1.1 Calculating entropy

Decide a matrix D of m alternatives and n attributes (criteria):

$$D = \begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \cdots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \tag{1}$$

Then define the attribute j, p_{ij}:

$$p_{ij} = \frac{x_{ij}}{\sum_{i=1}^{m} x_{ij}}, \text{ for } i=1, 2,\ldots, m; j= 1, 2,\ldots, n \tag{2}$$

The entropy $\boldsymbol{E}_j$ of the set of attribute j is

$$E_j = -k\sum_{i=1}^{m} p_{ij} \ln p_{ij}, \text{ for } i=1, 2,\ldots, m; j= 1, 2,\ldots, n \tag{3}$$

where $k = \frac{1}{\ln m}$, is a constant that guarantees that $0 \le E_j \le 1$.

2.1.2 Calculating the entropy weight

The degree of diversification d_j of the information provided by attribute j can be defined as

$$d_j = 1 - E_j, \text{ for } i=1, 2,\ldots, m; j= 1, 2,\ldots, n \tag{4}$$

Then the best weight set we can expect, instead of the equal weight, is

$$w_j = \frac{d_j}{\sum_{j=1}^{n} d_j}, \text{ for } i=1, 2,\ldots, m; j= 1, 2,\ldots, n \tag{5}$$

2.2 Grey relational analysis

GRA can be used to determine the relationships between one major sequence and the other sequences in a given system. Unlike statistical correlation analysis, which measures the relationship between any two random variables, GRA tries to find the relationships between one reference sequence and other comparative sequences by viewing the reference sequence as the desired goal (Hu et al., 2003). In other words, to identify dominant factors that can affect interactive development between manufacturing and logistics industries, given one reference sequence with respect to an evaluation factor in one industry (e.g., manufacturing), and comparative sequences with respect to all evaluation factors in the other industry (e.g., logistics), we can easily find the most influential factor among comparative sequences, and vice versa.

GRA includes four main steps (Kuo, Yang, and Huang, 2008):

Step 1: Grey relational generating;

Step 2: Reference sequence definition;

Step 3: Grey relational coefficient calculation; and

Step 4: Grey relational grade calculation.

The details of the proposed GRA procedure are presented below.

2.2.1 Grey relational generating

When the units in which performance is measured differ for different attributes, the influence of some attributes may be neglected (Deng, 1982). This may also occur if some performance attributes have a very large range (Luo et al., 2016). In addition, differences in the goals and directions of these attributes will lead to incorrect results in the analysis (Huang and Liao, 2003). Therefore, it is necessary to process all performance values for every alternative into a comparability sequence in a process analogous to normalization (Kuo, Yang, and Huang, 2008).
If there are m alternatives and n attributes, the ith alternative can be expressed as $Y_i = (y_{i1}, y_{i2},\ldots,y_{ij},\ldots, y_{in})$, where y_{ij} is the performance value of attribute j for alternative i. The term Y_i can be translated into the comparability sequence $X_i = (x_{i1}, x_{i2},\ldots, x_{ij},\ldots, x_{in})$. In this paper, all selected attributes in manufacturing and logistics industries are the-larger-the-better attributes, so the following equation can be used:

$$x_{ij} = \frac{y_{ij} - \min\left\{y_{ij}, i=1,2,\ldots,m\right\}}{\max\left\{y_{ij}, i=1,2,\ldots,m\right\} - \min\left\{y_{ij}, i=1,2,\ldots,m\right\}} \tag{6}$$

for i=1, 2,…, m; j= 1, 2,…, n.

2.2.2 Reference sequence definition

After grey relational generating, all performance values are scaled to the interval [0,1]. For an attribute j for alternative i, if the value x_{ij} processed by the grey relational generating procedure is equal to 1 or nearer to 1 than the value for any other alternative, then the performance of alternative i is the best for attribute j. Therefore, an alternative will be the best choice if all of its performance values are closest to or equal to 1. However, this type of alternative does not usually exist. In this paper, the attributes of the logistics industry are defined as the sequence X_i as $(x_{i1}, x_{i2},\ldots, x_{ij},\ldots, x_{in})$. Meanwhile, the attributes of the manufacturing industry are defined as the reference sequence Y_i as $(y_{i1}, y_{i2},\ldots,y_{ij},\ldots, y_{in})$. Our aim is to find an alternative, whose comparability sequence is closest to the reference sequence.

2.2.3 Grey relational coefficient calculation

Grey relational coefficient (GRC) is used to determine how close x_{ij} is to y_{ij}. The larger the GRC, the closer x_{ij} and y_{ij} are. The GRC can be calculated as

$$\gamma\left(y_{ij}, x_{ij}\right) = \frac{\Delta_{\min} + \zeta\Delta_{\max}}{\Delta_{ij} + \zeta\Delta_{\max}}, \text{ for } i=1, 2,\ldots, m;\ j= 1, 2,\ldots, n \tag{7}$$

where $\gamma\left(y_{ij}, x_{ij}\right)$ is the GRC between y_{ij} and x_{ij}, and

$$\Delta_{ij} = \left|y_{ij} - x_{ij}\right|,$$

$$\Delta_{\min} = \min\left\{\Delta_{ij}, i=1,2,\ldots m;\ j=1,2,\ldots n\right\},$$

$\Delta_{\max} = \max\left\{\Delta_{ij}, i = 1,2,\ldots m;\ j = 1,2,\ldots n\right\}$, and

ζ is the distinguishing coefficient; $\zeta \in [0,1]$.

The purpose of the distinguishing coefficient is to expand or compress the range of the grey relational coefficient. In this study, we initially set the distinguishing coefficient to 0.5.

2.2.4 Grey relational grade calculation

After calculating the GRC, $\gamma\left(y_{ij}, x_{ij}\right)$, the grey relational grade (GRG) can be calculated according to

$$\Gamma\left(Y_i, X_i\right) = \sum_{j=1}^{n} w_j \gamma\left(y_{ij}, x_{ij}\right), \text{ for } i=1, 2,\ldots, m;\ j=1, 2,\ldots, n \quad (8)$$

where $\Gamma\left(Y_i, X_i\right)$ is the GRG between X_i and Y_i, and represents the level of correlation between the reference sequence and the comparability sequence. w_j is the weight for attribute j and is calculated using Eq. (5). GRG indicates the degree of similarity between the comparability sequence and the reference sequence (Wei, 2011). Therefore, if a comparability sequence for an alternative has the highest GRG with the reference sequence, then it is most similar to the reference sequence.

3 Empirical study

3.1 Data collection

According to pervious research, many indicators can be used to evaluate manufacturing development (e.g., output, provincial output, tertiary industry output, industrial added value) and logistics (e.g., freight volume, retail sales of consumer goods, turnover volume, national transportation line length, fixed assets investment, number of employees) (Fan, Lin, and Gu, 2011; Wang and Chen, 2010; Wang and Li, 2013).

Data for this study for all selected indicators were taken from the *Taiwan Statistical Yearbook* during the period 2005–2014. Table 1 and Table 2 list indicators for the manufacturing and logistics industries.

Table 1: Indicators of logistics industry

Year	X_1 Total output of transportation and storage (NT$ million)	X_2 Total freight volume (1000 MTs)	X_3 Gross Fixed Capital Formation of transportation (NT$ million)	X_4 Year-end No. of Operating Vehicles
2005	993370	842544	213793	84347
2006	1026304	873094	165141	80737
2007	1070800	904859	164264	76294
2008	1069997	883010	120799	73210
2009	934271	843801	127675	70844
2010	1100761	887414	173436	72126
2011	1090176	895760	178597	73492
2012	1127429	905146	184161	74723
2013	1133546	807640	186341	81760
2014	1196146	810654	217470	82302

Year	X_5 No. of Vehicle Kilometers (1000 Truck-kms)	X_6 Freight Tonnage (1000 MTs)	X_7 Length of Roads (km)	X_8 Number of employees Transportation & Storage(Thousand)
2005	4959971	561831	37336	412
2006	4952581	594214	38297	417
2007	4863470	617567	38526	415
2008	4730607	604137	39315	414
2009	4466423	596742	39849	402
2010	4628448	628 167	40353	404
2011	4552187	638499	40995	411
2012	4599969	653265	41924	414
2013	4171623	551430	42520	425
2014	4212537	541939	41916	433

Data Sources: The website of *Directorate General of Budget, Accounting and Statistics, Executive Yuan of Taiwan*.

Table 2: Indicators of manufacturing industry

Year	Y_1 Manufacturing output (NT$ million)	Y_2 Industrial Production	Y_3 Gross domestic manufacturing production deflator (%)	Y_4 Manufacturing fixed capital consumption (NT$ million)	Y_5 Manufacturing employment Compensation (NT$ million)
2005	13133742	73	128	715688	1400107
2006	14515324	76	124	782351	1492499
2007	15866852	83	118	857874	1538873
2008	15981326	82	111	950651	1568294
2009	13559985	76	109	1007982	1376113
2010	17753198	96	106	1043332	1538706
2011	18723508	100	100	1101020	1664002
2012	18327450	100	97	1147402	1697072
2013	18380201	100	101	1137998	1719388
2014	19182851	107	102	1188895	1811810

Data Sources: The website of Directorate General of Budget, Accounting and Statistics, Executive Yuan of Taiwan.

3.2 GRA with entropy

The main purpose of grey relational generating is to transfer the original data into comparability sequences (Kuo, Yang, and Huang, 2008). The attributes for the two industries are all the-larger-the-better attributes, so we normalize Table 1 and Table 2 using Eq. (6). The grey relational generating results are shown in Table 3 and Table 4.

Table 3: Normalized data of logistics industry

Year	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8
2005	0.2257	0.3580	0.9620	1.0000	1.0000	0.1787	0.0000	0.3226
2006	0.3514	0.6713	0.4587	0.7327	0.9906	0.4696	0.1854	0.4839
2007	0.5214	0.9971	0.4496	0.4036	0.8776	0.6793	0.2296	0.4194
2008	0.5183	0.7730	0.0000	0.1752	0.7091	0.5587	0.3818	0.3871
2009	0.0000	0.3709	0.0711	0.0000	0.3739	0.4923	0.4848	0.0000
2010	0.6358	0.8181	0.5445	0.0949	0.5795	0.7746	0.5820	0.0645
2011	0.5953	0.9037	0.5979	0.1961	0.4827	0.8674	0.7058	0.2903
2012	0.7376	1.0000	0.6554	0.2873	0.5433	1.0000	0.8850	0.3871
2013	0.7610	0.0000	0.6780	0.8084	0.0000	0.0853	1.0000	0.7419
2014	1.0000	0.0309	1.0000	0.8486	0.0519	0.0000	0.8835	1.0000

Table 4: Normalized data of manufacturing industry

Year	Y_1	Y_2	Y_3	Y_4	Y_5
2005	0.0000	0.0000	1.0000	0.0000	0.0551
2006	0.2284	0.0990	0.8592	0.1409	0.2671
2007	0.4518	0.2863	0.6666	0.3005	0.3736
2008	0.4707	0.2645	0.4547	0.4965	0.4411
2009	0.0705	0.0763	0.3981	0.6177	0.0000
2010	0.7637	0.6651	0.3085	0.6924	0.3732
2011	0.9241	0.7971	0.1008	0.8143	0.6608
2012	0.8586	0.7876	0.0000	0.9123	0.7367
2013	0.8673	0.8041	0.1251	0.8924	0.7879
2014	1.0000	1.0000	0.1613	1.0000	1.0000

Taking Y_1 as the reference sequence, results for $\Delta_{ij} = \left| y_{ij} - x_{ij} \right|$ calculated are shown in Table 5. Results for Y_2, Y_3, Y_4, and Y_5 as the reference sequences are shown in Appendix 1.

Table 5: Difference series with reference sequence Y_1

Year	Y_1	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8
2005		0.2257	0.3580	0.9620	1.0000	1.0000	0.1787	0.0000	0.3226
2006		0.1230	0.4429	0.2303	0.5043	0.7622	0.2412	0.0430	0.2555
2007		0.0695	0.5452	0.0022	0.0482	0.4258	0.2275	0.2223	0.0325
2008		0.0475	0.3022	0.4707	0.2955	0.2383	0.0880	0.0890	0.0836
2009		0.0705	0.3004	0.0007	0.0705	0.3035	0.4218	0.4143	0.0705
2010		0.1279	0.0545	0.2192	0.6687	0.1842	0.0109	0.1817	0.6991
2011		0.3287	0.0203	0.3262	0.7280	0.4413	0.0567	0.2182	0.6337
2012		0.1210	0.1414	0.2032	0.5713	0.3152	0.1414	0.0264	0.4715
2013		0.1064	0.8673	0.1893	0.0589	0.8673	0.7821	0.1327	0.1254
2014		0.0000	0.9691	0.0000	0.1514	0.9481	1.0000	0.1165	0.0000

According to Table 5, $\Delta_{\max} = 1$ and $\Delta_{\min} = 0$, so all the GRCs can be calculated according to Eq. (7). With each year equally weighted, the average GRCs for reference sequence Y_1 for 10 years are shown in Table 6. The average GRCs for Y_2, Y_3, Y_4, andY_5 as the reference sequences are shown in Appendix 2. Aggregated GRC results are presented in Table 7.

Table 6: Grey relational coefficients with reference sequence Y_1

Year	Y_1	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8
2005		0.6890	0.5828	0.3420	0.3333	0.3333	0.7367	1.0000	0.6078
2006		0.8025	0.5303	0.6847	0.4979	0.3961	0.6746	0.9208	0.6618
2007		0.8779	0.4784	0.9956	0.9121	0.5401	0.6873	0.6923	0.9390
2008		0.9132	0.6233	0.5151	0.6285	0.6772	0.8504	0.8489	0.8567
2009		0.8765	0.6247	0.9987	0.8765	0.6223	0.5424	0.5469	0.8765
2010		0.7963	0.9017	0.6953	0.4278	0.7308	0.9787	0.7335	0.4170
2011		0.6033	0.9609	0.6052	0.4072	0.5312	0.8981	0.6961	0.4410
2012		0.8052	0.7795	0.7111	0.4667	0.6133	0.7795	0.9498	0.5147
2013		0.8246	0.3657	0.7254	0.8946	0.3657	0.3900	0.7903	0.7995
2014		1.0000	0.3403	1.0000	0.7675	0.3453	0.3333	0.8110	1.0000
AVG.		0.8188	0.6188	0.7273	0.6212	0.5155	0.6871	0.7990	0.7114

In this case, the importance of all indicators was not equal. Thus, the weights for all attributes were calculated using entropy. All the weights for W_X and W_Y calculated according to Eqs. (1)–(5) are listed in Table 7. The detailed calculation steps are presented in Appendix 3. GRG values calculated according to Eq. (8) are shown in Table 7.

Table 7: GRG Matrix of Manufacturing and logistics industries in Taiwan

	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	W_Y	GRG_Y	Ranking$_{(Y)}$
Y_1	0.8188	0.6188	0.7273	0.6212	0.5155	0.6871	0.7990	0.7114	0.2237	0.7095	3
Y_2	0.8051	0.5602	0.7431	0.6481	0.5175	0.6189	0.8181	0.7029	0.2376	0.7139	2
Y_3	0.5432	0.6131	0.5772	0.6671	0.7427	0.6513	0.5250	0.5885	0.1104	0.5966	5
Y_4	0.7618	0.5997	0.6533	0.5647	0.5239	0.6927	0.8620	0.6465	0.3330	0.6563	4
Y_5	0.8726	0.5382	0.7666	0.6876	0.5376	0.6114	0.7845	0.7865	0.0953	0.7371	1
W_X	0.0901	0.0335	0.6215	0.0727	0.0667	0.0721	0.0347	0.0088			
GRG_X	0.7713	0.5902	0.6936	0.6202	0.5460	0.6616	0.7929	0.6813			
Ranking$_{(X)}$	2	7	3	6	8	5	1	4			

3.3 Results

The GRG between the logistics indicators and manufacturing indicators is as follows: 0.7095 for manufacturing output (Y_1); 0.7139 for industrial production (Y_2); 0.5966 for gross domestic manufacturing production deflator (Y_3); 0.6563 for manufacturing fixed capital consumption (Y_4); and 0.7371 for manufacturing employment compensation (Y_5). Thus, the GRG ranking for manufacturing indicators is $Y_5 \succ Y_2 \succ Y_1 \succ Y_4 \succ Y_3$. Therefore, the following conclusion can be drawn:

Result 1: The dominant manufacturing factor influencing the development of the logistics industry is employment compensation.

The GRG between the manufacturing indicators and logistics indicators is as follows: 0.7713 for total output of transportation and storage (X_1); 0.5902 for total freight volume (X_2); 0.6936 for gross fixed capital formation for transportation (X_3); 0.6202 for year-end number of operating vehicles (X_4); 0.5460 for number of vehicle kilometers (X_5); 0.6616 for freight tonnage (X_6); 0.7929 for length of roads (X_7); and 0.6813 for number of employees in transportation and storage (X_8). Thus, the GRG ranking for manufacturing indicators is $X_7 \succ X_1 \succ X_3 \succ X_8 \succ X_6 \succ X_4 \succ X_2 \succ X_5$. Therefore, the following conclusion can be drawn:

Result 2: The dominant logistics factor influencing the development of manufacturing industry is length of roads.

According to Table 8, the GRG for the 13 indicators selected ranges from 0.5155 to 0.8726. The following conclusion can be drawn:

Result 3: A fairly strong interaction exists between logistics and manufacturing industries.

4 Discussion and conclusions

We used GRA with entropy to measure interaction between two industry sectors. The results in Table 7 show the following. (1) The dominant manufacturing factor influencing the development of the logistics industry is employment compensation. (2) The dominant logistics factor influencing the development of the manufacturing sector is length of roads. (3) A fairly strong interaction exists between logistics and manufacturing industries.

With higher compensation, manufacturing employees may have a higher consumption capacity, which could enhance the social demand for commodities, promoting the development of the logistics industry. Accordingly, it can be inferred that logistics development is closely related to the level of employment compensation. There is a consensus that roads are very important for social economic development. On one hand, road accessibility affects the layout of the manufacturing industry, because factories are usually built in easily accessible areas. On the other hand, the length of roads determines logistics capability in Taiwan, and thus affects manufacturing feasibility. Therefore, it can be inferred that manufacturing development is closely related to the length of roads. In summary, to promote effective interaction between manufacturing and logistics industries, the government should build more roads to extend the total road length and manufacturers should pay more attention to employment compensation.

Both manufacturing and logistics industries play very important roles in social development and economic growth. Interaction between these two sectors is attracting increasing attention and some useful research has been carried out. However, previous studies mainly focused on the importance of interaction between manufacturing and logistics industries, and differences among indicators (attributes) have largely been ignored, with all indicators set to be equally

weighted. The highlights of this study are twofold: (1) we take into account that the importance of attributes to the reference sequence differs, so we obtain weights for all attributes using the entropy method; and (2) we provide a new approach for measuring interaction between two industries.
Although GRA with entropy overcomes many of the shortcomings of other methods, our study has several limitations. First, we selected just eight logistics and five manufacturing indicators; other measurable indicators could also be considered. Second, the weight for each attribute was obtained using the entropy method. It would be more reasonable to obtain the weights by combining practical knowledge, expert analysis, and intelligent systems. Third, our conclusions are only for Taiwan. Logistics development is also affected by area, topography, and other natural factors, so development patterns for the logistics industry in different regions may differ. More data from other countries could be considered.
This research can be extended in a number of ways. First, multiple-attribute decision-making methods such as analytic hierarchy process and analytic network process could be used for weight calculations. Second, a separate weight for each year should be considered. Third, GRCs can be regarded as a partial GRG, so the relationship between attributes could also be analyzed. Fourth, time differences in interactions between manufacturing and logistics industries could be investigated. In addition, the GM (1,1) model could be considered during simulation of original sequences.

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References

[1] J. W. K. Chan, Competitive strategies and manufacturing logistics: An empirical study of Hong Kong manufacturers, *International Journal of Physical Distribution & Logistics Management*, **35**(1), (2005),20-43.
[2] L.Y. Chan, M. C. Chang, and C. C. Hsu, Vertical Disintegration and Industry Agglomeration in Taiwan's Manufacturing Sector, *Taiwan Economic Review*, **32**(4), (2004), 483-511.
[3] S. H. Chiang, and J. T. Hwang, An Investigation of Urban Agglomeration Economies in Taiwanese Manufacturing, *Journal of Taiwan Land Research*, **10**(2), (2007), 127-149.
[4] T. M. Choi, S. W. Wallace and Y. L. Wang, Risk management and coordination in service supply chains: information, logistics and outsourcing, *Journal of the Operational Research Society*, **67**(2), (2016), 159-164.
[5] J. L. Deng, Control problems of grey systems, *Systems & Control Letters*, **1**(5), (1982), 288-294.

[6] J. Fagerberg and B. Verspagen, Technology-gaps, innovation-diffusion and transformation: an evolutionary interpretation, *Research Policy*, **31**(8–9), (2002), 1291-1304.

[7] S. Hertz, and M. Alfredsson, Strategic development of third party logistics providers, *Industrial Marketing Management*, **32**(2), (2003), 139-149.

[8] P. F. Hsu and P. C. Chien, Optimal selection of media agencies for an advertiser using the GRA and Entropy, *Journal of Grey System*, **20**(1), (2008), 27-38.

[9] P. F. Hsu and M. H. Kuo, An application of the GRA & Entropy to select a city in China for an international business office center, *Journal of Grey System*, **19**(3), (2007), 269-282.

[10] Y. C. Hu, Tolerance rough sets for pattern classification using multiple grey single-layer perceptrons, *Neurocomputing*, **179**(C), (2016), 144-151.

[11] Y. C. Hu, A novel flow-based method using grey relational analysis for pattern classification, *International Journal of Information Technology and Decision Making*, **12**(1), (2013), 75-93.

[12] Y. C. Hu, R. S. Chen, Y. T. Hsu, and G. H. Tzeng, Grey self-organizing feature maps, *Neurocomputing*, **48**(1), (2002), 863-877.

[13] J. T. Huang and Y. S. Liao, Optimization of machining parameters of Wire-EDM based on Grey relational and statistical analyses, *International Journal of Production Research*, **41**(8), (2003), 1707-1720.

[14] M. Q. Huang and B. Wang, Factors influencing CO2 emissions in China based on grey relational analysis, *Energy Sources Part A-Recovery Utilization and Environmental Effects*, **38**(4), (2016), 555-561.

[15] B. N. Hwang, T. T. Chen, and J. T. Lin, 3PL selection criteria in integrated circuit manufacturing industry in Taiwan, *Supply Chain Management-an International Journal*, **21**(1), (2016), 103-124.

[16] J. Fan, L. S. Lin, and C. M. Gu, Research on manufacturing and logistics linkage development based on the Grey correlation model - Case study of Zhejiang Province, *The 2nd International Conference of Electrical and Electronics Engineering*, 2011, Macau, China.

[17] Y. Kuo, T. Yang, and G. W. Huang, The use of grey relational analysis in solving multiple attribute decision-making problems, *Computers & Industrial Engineering*, **55**(1), (2008), 80-93.

[18] F. Li, C. Jin, R. Wang, H. Wang, and L. Yang, A 3PL supplier selection model based on fuzzy sets, *Computers & Operations Research*, **39**(8), (2012), 1879-1884.

[19] X. M. Li, K. W. Hipel, and Y. G. Dang, An improved grey relational analysis approach for panel data clustering, *Expert Systems with Applications*, **42**(23), (2015), 9105-9116.

[20] S. Liu and Y. Lin, *Grey Information: Theory and Practical Applications*, Springer-Lerlag, London, 2006.

[21] X. L. Luo, Y. Z. Wang, J. Zhao, Y. Chen, S. P. Mo, and Y. L. Gong, Grey relational analysis of an integrated cascade utilization system of geothermal water, *International Journal of Green Energy*, **13**(1), (2016),14-27.
[22] J. A. T. Machado, Entropy analysis of systems exhibiting negative probabilities, *Communications in Nonlinear Science and Numerical Simulation*, **36**, (2016), 58-64.
[23] A. Marasco, Third-party logistics: A literature review, *International Journal of Production Economics*, **113**(1), (2008), 127-147.
[24] O. Mortensen and O. W. Lemoine, Integration between manufacturers and third party logistics providers? *International Journal of Operations & Production Management*, **28**(4), (2008), 331-359.
[25] B. H. Peng and L. Q. Feng, A Study on the Symbiotic Mechanism of Modern Logistics Industry and Advanced Manufacturing, *Journal of Business Economics*, **1**(1), (2010), 18-25.
[26] S. Rajesh, S. Rajakarunakaran, and R. Sudhkarapandian, Optimization of the red mud-aluminum composite in the turning process by the Grey relational analysis with entropy, *Journal of Composite Materials*, **48**(17), (2014), 2097-2105.
[27] E. Sandberg and M. Abrahamsson, Logistics capabilities for sustainable competitive advantage, *International Journal of Logistics*, **14**(1), (2011), 61-75.
[28] K. C. Shang and P. B. Marlow, Logistics capability and performance in Taiwan's major manufacturing firms, *Transportation Research Part E: Logistics and Transportation Review*, **41**(3), (2005), 217-234.
[29] Y. Y. Shi, A. Zhang, T. Arthanari, Y. P. Liu, and T. C. E. Cheng, Third-party purchase: An empirical study of third-party logistics providers in China, *International Journal of Production Economics*, **171**(3), (2016), 189-200.
[30] J. J. Shuai and W. W. Wu, Evaluating the influence of E-marketing on hotel performance by DEA and grey entropy, *Expert Systems with Application*s, **38**(7), (2011), 8763-8769.
[31] D. Stosic, D. Stosic, T. Ludermir, W. de Oliveira, and T. Stosic, Foreign exchange rate entropy evolution during financial crises, *Physica a-Statistical Mechanics and Its Applications*, **449**, (2016), 233-239.
[32] C. C. Sun, Combining grey relation analysis and entropy model for evaluating the operational performance: an empirical study, *Quality & Quantity*, **48**(3), (2014), 1589-1600.
[33] A. Szirmai, Industrialization as an engine of growth in developing countries, 1950–2005, *Structural Change and Economic Dynamics*, **23**(4), (2012), 406-420.
[34] A. Szirmai, and B. Verspagen, Manufacturing and economic growth in developing countries, 1950–2005, *Structural Change and Economic Dynamics*, **34**, (2015), 46-59.

[35] A. Verma, S. Sarangi, and M. H. Kolekar, Stator winding fault prediction of induction motors using multiscale entropy and grey fuzzy optimization methods, *Computers & Electrical Engineering*, **40**(7), (2014), 2246-2258.

[36] H. Voordijk, Obstacles and preconditions for logistics and manufacturing improvements in Africa - a case study, *International Journal of Operations & Production Management*, **19**(3-4), (1999), 293-307.

[37] Z. Z. Wang and G. Y. Chen, Empirical Analysis of Interactive Development between Manufacturing Sub-sectors and Logistics Industry: Based on Gray Correlational Model, *Journal of Shanghai University of Finance and Economics*, **12**(3), (2010), 65-74.

[38] Z. Wang, Interactive development of Manufacturing and Logistics: A literature review, *Journal of Management*, **27**(1), (2014), 41-47,57.

[39] Z. Wang and G. Chen, Analysis on the Evolutionary Game of Interactive Development between Manufacturing and Logistics Industry, *Economic Issues in China*, **2**, (2012), 86-97.

[40] G. W. Wei, Grey relational analysis model for dynamic hybrid multiple attribute decision making, *Knowledge-Based Systems*, **24**(5),(2011), 672-679.

[41] K. L. Wen, Grey Systems: Modeling and Prediction, *Yangs Scientific Research Institute*, AZ, 2004.

[42] L. Wu, Q. S. Zhang, K. Guo, and Q. R. Qiu, Identification of Overlapping Community Structure with Grey Relational Analysis in Social Networks, *Journal of Grey System*, **28**(1), (2016), 98-108.

[43] W. W. Wu, An integrated solution for benchmarking using DEA, gray entropy, and Borda count, *Service Industries Journal*, **32**(2), (2012), 321-335.

[44] X. Wang and W. Li, Analysis on the grey correlation between manufacturing and logistics industry in Dongguan, *The 9th International Conference on Computational Intelligence and Security*, 2013, Emeishan, China.

[45] M. J. Xu, P. J. Shang and J. J. Huang, Modified generalized sample entropy and surrogate data analysis for stock markets, *Communications in Nonlinear Science and Numerical Simulation*, **35**, (2016), 17-24.

Appendix 1

Table 8: Difference series with reference sequence Y_2

Year	Y_2	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8
2005		0.2257	0.3580	0.9620	1.0000	1.0000	0.1787	0.0000	0.3226
2006		0.2525	0.5723	0.3597	0.6337	0.8917	0.3706	0.0864	0.3849
2007		0.2350	0.7108	0.1633	0.1173	0.5913	0.3930	0.0568	0.1331
2008		0.2538	0.5085	0.2645	0.0893	0.4446	0.2942	0.1172	0.1226
2009		0.0763	0.2946	0.0052	0.0763	0.2977	0.4160	0.4085	0.0763
2010		0.0293	0.1531	0.1206	0.5702	0.0856	0.1095	0.0831	0.6006
2011		0.2017	0.1067	0.1992	0.6009	0.3143	0.0703	0.0912	0.5067
2012		0.0500	0.2124	0.1322	0.5004	0.2443	0.2124	0.0974	0.4005
2013		0.0432	0.8041	0.1261	0.0043	0.8041	0.7189	0.1959	0.0622
2014		0.0000	0.9691	0.0000	0.1514	0.9481	1.0000	0.1165	0.0000

Table 9: Difference series with reference sequence Y_3

Year	Y_3	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8
2005		0.7743	0.6420	0.0380	0.0000	0.0000	0.8213	1.0000	0.6774
2006		0.5078	0.1879	0.4005	0.1265	0.1314	0.3896	0.6738	0.3753
2007		0.1452	0.3305	0.2169	0.2629	0.2110	0.0128	0.4370	0.2472
2008		0.0636	0.3183	0.4547	0.2795	0.2543	0.1040	0.0730	0.0676
2009		0.3981	0.0272	0.3270	0.3981	0.0241	0.0942	0.0867	0.3981
2010		0.3273	0.5097	0.2360	0.2135	0.2710	0.4661	0.2735	0.2440
2011		0.4945	0.8029	0.4971	0.0953	0.3819	0.7666	0.6050	0.1895
2012		0.7376	1.0000	0.6554	0.2873	0.5433	1.0000	0.8850	0.3871
2013		0.6358	0.1251	0.5529	0.6833	0.1251	0.0399	0.8749	0.6168
2014		0.8387	0.1304	0.8387	0.6873	0.1094	0.1613	0.7222	0.8387

Table 10: Difference series with reference sequence Y_4

Year	Y_4	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8
2005		0.2257	0.3580	0.9620	1.0000	1.0000	0.1787	0.0000	0.3226
2006		0.2106	0.5304	0.3178	0.5918	0.8498	0.3287	0.0445	0.3430
2007		0.2209	0.6966	0.1491	0.1031	0.5771	0.3789	0.0709	0.1189
2008		0.0218	0.2764	0.4965	0.3213	0.2125	0.0622	0.1148	0.1094
2009		0.6177	0.2468	0.5466	0.6177	0.2437	0.1254	0.1329	0.6177
2010		0.0566	0.1258	0.1479	0.5974	0.1129	0.0822	0.1104	0.6279
2011		0.2190	0.0894	0.2164	0.6182	0.3316	0.0531	0.1085	0.5240
2012		0.1747	0.0877	0.2569	0.6250	0.3690	0.0877	0.0273	0.5252
2013		0.1315	0.8924	0.2145	0.0840	0.8924	0.8072	0.1076	0.1505
2014		0.0000	0.9691	0.0000	0.1514	0.9481	1.0000	0.1165	0.0000

Table 11: Difference series with reference sequence Y_5

Year	Y_5	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8
2005		0.1706	0.3029	0.9069	0.9449	0.9449	0.1236	0.0551	0.2675
2006		0.0843	0.4042	0.1916	0.4655	0.7235	0.2024	0.0817	0.2167
2007		0.1478	0.6235	0.0761	0.0301	0.5040	0.3058	0.1440	0.0458
2008		0.0772	0.3319	0.4411	0.2659	0.2680	0.1176	0.0593	0.0540
2009		0.0000	0.3709	0.0711	0.0000	0.3739	0.4923	0.4848	0.0000
2010		0.2626	0.4450	0.1713	0.2782	0.2063	0.4014	0.2088	0.3087
2011		0.0654	0.2430	0.0629	0.4647	0.1780	0.2066	0.0451	0.3704
2012		0.0009	0.2633	0.0812	0.4494	0.1933	0.2633	0.1484	0.3496
2013		0.0269	0.7879	0.1099	0.0205	0.7879	0.7026	0.2121	0.0459
2014		0.0000	0.9691	0.0000	0.1514	0.9481	1.0000	0.1165	0.0000

Appendix 2

Table 12: Grey relational coefficients with reference sequence Y_2

Year	Y_2	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8
2005		0.6890	0.5828	0.3420	0.3333	0.3333	0.7367	1.0000	0.6078
2006		0.6645	0.4663	0.5816	0.4410	0.3593	0.5743	0.8526	0.5650
2007		0.6802	0.4130	0.7538	0.8100	0.4582	0.5599	0.8981	0.7898
2008		0.6633	0.4958	0.6540	0.8485	0.5294	0.6296	0.8101	0.8031
2009		0.8676	0.6293	0.9898	0.8676	0.6268	0.5459	0.5504	0.8676
2010		0.9446	0.7656	0.8057	0.4672	0.8538	0.8204	0.8575	0.4543
2011		0.7125	0.8242	0.7151	0.4542	0.6140	0.8767	0.8457	0.4967
2012		0.9090	0.7019	0.7909	0.4998	0.6718	0.7019	0.8370	0.5552
2013		0.9205	0.3834	0.7986	0.9915	0.3834	0.4102	0.7185	0.8894
2014		1.0000	0.3403	1.0000	0.7675	0.3453	0.3333	0.8110	1.0000
AVG.		0.8051	0.5602	0.7431	0.6481	0.5175	0.6189	0.8181	0.7029

Table 13: Grey relational coefficients with reference sequence Y_3

Year	Y_3	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8
2005		0.3924	0.4378	0.9293	1.0000	1.0000	0.3784	0.3333	0.4247
2006		0.4961	0.7268	0.5552	0.7980	0.7919	0.5620	0.4260	0.5712
2007		0.7749	0.6020	0.6974	0.6554	0.7032	0.9751	0.5336	0.6692
2008		0.8872	0.6111	0.5237	0.6414	0.6628	0.8278	0.8726	0.8809
2009		0.5567	0.9484	0.6046	0.5567	0.9540	0.8415	0.8523	0.5567
2010		0.6044	0.4952	0.6793	0.7007	0.6485	0.5176	0.6464	0.6721
2011		0.5027	0.3837	0.5015	0.8399	0.5669	0.3948	0.4525	0.7251
2012		0.4040	0.3333	0.4327	0.6351	0.4792	0.3333	0.3610	0.5636
2013		0.4402	0.7998	0.4749	0.4225	0.7998	0.9262	0.3637	0.4477
2014		0.3735	0.7932	0.3735	0.4211	0.8205	0.7561	0.4091	0.3735
AVG.		0.5432	0.6131	0.5772	0.6671	0.7427	0.6513	0.5250	0.5885

Table 14: Grey relational coefficients with reference sequence Y_4

Year	Y_4	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8
2005		0.6890	0.5828	0.3420	0.3333	0.3333	0.7367	1.0000	0.6078
2006		0.7037	0.4852	0.6114	0.4580	0.3704	0.6034	0.9183	0.5931
2007		0.6936	0.4179	0.7702	0.8290	0.4642	0.5689	0.8758	0.8079
2008		0.9583	0.6440	0.5017	0.6088	0.7017	0.8894	0.8133	0.8204
2009		0.4474	0.6695	0.4778	0.4474	0.6723	0.7995	0.7900	0.4474
2010		0.8983	0.7990	0.7717	0.4556	0.8158	0.8589	0.8191	0.4433
2011		0.6955	0.8483	0.6979	0.4471	0.6013	0.9041	0.8217	0.4883
2012		0.7410	0.8508	0.6606	0.4444	0.5754	0.8508	0.9483	0.4877
2013		0.7918	0.3591	0.6998	0.8561	0.3591	0.3825	0.8230	0.7686
2014		1.0000	0.3403	1.0000	0.7675	0.3453	0.3333	0.8110	1.0000
AVG.		0.7618	0.5997	0.6533	0.5647	0.5239	0.6927	0.8620	0.6465

Table 15: Grey relational coefficients with reference sequence Y_5

Year	Y_5	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8
2005		0.7456	0.6227	0.3554	0.3460	0.3460	0.8018	0.9008	0.6515
2006		0.8557	0.5530	0.7230	0.5179	0.4087	0.7118	0.8595	0.6976
2007		0.7719	0.4450	0.8680	0.9433	0.4980	0.6205	0.7764	0.9161
2008		0.8663	0.6010	0.5313	0.6529	0.6511	0.8096	0.8939	0.9025
2009		1.0000	0.5741	0.8755	1.0000	0.5721	0.5039	0.5077	1.0000
2010		0.6557	0.5291	0.7448	0.6425	0.7079	0.5547	0.7054	0.6183
2011		0.8843	0.6730	0.8883	0.5183	0.7374	0.7076	0.9173	0.5744
2012		0.9981	0.6550	0.8603	0.5267	0.7212	0.6550	0.7712	0.5885
2013		0.9489	0.3882	0.8198	0.9605	0.3882	0.4158	0.7021	0.9159
2014		1.0000	0.3403	1.0000	0.7675	0.3453	0.3333	0.8110	1.0000
AVG.		0.8726	0.5382	0.7666	0.6876	0.5376	0.6114	0.7845	0.7865

Appendix 3

The detailed calculation steps of using Entropy to obtain weights.

According to Eq. (2), the value of p_{ij} could be calculated, as shown in Table 16 and Table 17.

According to Eqs. (3) - (5), the Entropy E_j, d_j, w_j could be calculated, as shown in Table 18 and Table 19.

Table 16: p_{ij} value of logistics indicators

Year	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8
2005	0.0925	0.0974	0.1235	0.1096	0.1075	0.0938	0.0931	0.0993
2006	0.0955	0.1009	0.0954	0.1049	0.1073	0.0992	0.0955	0.1006
2007	0.0997	0.1046	0.0949	0.0991	0.1054	0.1031	0.0961	0.1001
2008	0.0996	0.1020	0.0698	0.0951	0.1025	0.1009	0.0980	0.0998
2009	0.0870	0.0975	0.0737	0.0920	0.0968	0.0997	0.0994	0.0969
2010	0.1025	0.1025	0.1002	0.0937	0.1003	0.1049	0.1006	0.0974
2011	0.1015	0.1035	0.1031	0.0955	0.0987	0.1066	0.1022	0.0991
2012	0.1049	0.1046	0.1063	0.0971	0.0997	0.1091	0.1045	0.0998
2013	0.1055	0.0933	0.1076	0.1062	0.0904	0.0921	0.1060	0.1025
2014	0.1113	0.0937	0.1256	0.1069	0.0913	0.0905	0.1045	0.1044

Table 17: p_{ij} value of manufacturing indicators

Year	Y_1	Y_2	Y_3	Y_4	Y_5
2005	0.0794	0.0818	0.1169	0.0721	0.0886
2006	0.0877	0.0856	0.1129	0.0788	0.0944
2007	0.0959	0.0927	0.1074	0.0864	0.0974
2008	0.0966	0.0919	0.1013	0.0957	0.0992
2009	0.0820	0.0847	0.0997	0.1015	0.0871
2010	0.1073	0.1071	0.0972	0.1050	0.0973
2011	0.1132	0.1121	0.0913	0.1108	0.1053
2012	0.1108	0.1118	0.0884	0.1155	0.1074
2013	0.1111	0.1124	0.0919	0.1146	0.1088
2014	0.1160	0.1199	0.0930	0.1197	0.1146

Table 18: E_j, d_j, w_j values of logistics indicators

Year	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8
2005	-0.2202	-0.2268	-0.2583	-0.2423	-0.2398	-0.2220	-0.2210	-0.2294
2006	-0.2243	-0.2314	-0.2241	-0.2365	-0.2396	-0.2293	-0.2243	-0.2310
2007	-0.2298	-0.2361	-0.2234	-0.2291	-0.2372	-0.2343	-0.2251	-0.2304
2008	-0.2297	-0.2329	-0.1857	-0.2238	-0.2335	-0.2314	-0.2277	-0.2300
2009	-0.2124	-0.2270	-0.1922	-0.2195	-0.2260	-0.2298	-0.2294	-0.2262
2010	-0.2334	-0.2335	-0.2305	-0.2218	-0.2307	-0.2365	-0.2311	-0.2269
2011	-0.2322	-0.2348	-0.2343	-0.2242	-0.2285	-0.2387	-0.2331	-0.2291
2012	-0.2366	-0.2361	-0.2383	-0.2264	-0.2299	-0.2417	-0.2361	-0.2300
2013	-0.2373	-0.2213	-0.2399	-0.2382	-0.2173	-0.2196	-0.2379	-0.2335
2014	-0.2444	-0.2218	-0.2606	-0.2390	-0.2185	-0.2174	-0.2360	-0.2359
SUM	-2.3004	-2.3018	-2.2873	-2.3008	-2.3009	-2.3008	-2.3017	-2.3024
E_j	0.9990	0.9996	0.9934	0.9992	0.9993	0.9992	0.9996	0.9999
d_j	0.0010	0.0004	0.0066	0.0008	0.0007	0.0008	0.0004	0.0001
w_j	0.0901	0.0335	0.6215	0.0727	0.0667	0.0721	0.0347	0.0088

Table 19: E_j, d_j, w_j values of manufacturing indicators

Year	Y_1	Y_2	Y_3	Y_4	Y_5
2005	-0.2011	-0.2048	-0.2509	-0.1895	-0.2147
2006	-0.2135	-0.2104	-0.2462	-0.2002	-0.2228
2007	-0.2249	-0.2205	-0.2396	-0.2115	-0.2268
2008	-0.2258	-0.2193	-0.2320	-0.2246	-0.2292
2009	-0.2050	-0.2091	-0.2299	-0.2322	-0.2125
2010	-0.2395	-0.2393	-0.2265	-0.2367	-0.2268
2011	-0.2466	-0.2454	-0.2185	-0.2438	-0.2370
2012	-0.2438	-0.2449	-0.2144	-0.2493	-0.2396
2013	-0.2441	-0.2457	-0.2194	-0.2482	-0.2413
2014	-0.2498	-0.2543	-0.2209	-0.2541	-0.2483
SUM	-2.2942	-2.2937	-2.2984	-2.2901	-2.2990
E_j	0.9963	0.9961	0.9982	0.9946	0.9984
d_j	0.0037	0.0039	0.0018	0.0054	0.0016
w_j	0.2237	0.2376	0.1104	0.3330	0.0953