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Full Length Research Paper

Cross national comparison of innovation efficiency and policy application

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European Innovation Scoreboard (EIS) proposed the revision of the innovation indicators including innovation drivers, knowledge creation and innovation and entrepreneurship describe innovation input. Application and intellectual property describe innovation output. European Commission develops the EIS as the instrument evaluates and compares the innovation performance of the member States under the Lisbon Strategy. The EIS 2005 includes innovation indicators and trend analyses for all 25 EU Member States, as well as for Bulgaria, Romania, Turkey, Iceland, Norway, Switzerland, the US, and Japan. This study utilizes the data from EIS and applies Grey Relational Analysis (GRA) and Data Envelopment Analysis (DEA) to evaluate the innovation efficiency for 33 countries. This study also provides cross-national innovation policy analysis for leading innovation efficient countries. Denmark, German, Ireland, Luxemburg, Malta, and Switzerland are the most innovation efficiency countries among 33 countries in this study.

Key words: European innovation scoreboards, innovation efficiency, Grey relational analysis, data envelopment analysis, innovation policy.

INTRODUCTION

European Innovation Scoreboard (EIS) proposes the revision of the innovation indicators including innovation drivers, knowledge creation and innovation and entrepreneurship describes innovation input. Application and intellectual property describes innovation output (European Commission, 2005a).

European Commission develops the EIS as the instrument evaluating and comparing the innovation performance of the member States under the Lisbon Strategy. The EIS 2005 includes innovation indicators and trend analyses for all 25 EU Member States, as well as for Bulgaria, Romania, Turkey, Iceland, Norway, Switzerland, the US, and Japan (European Commission, 2005b).

Numerous studies research (Furman et al., 2002; Furman and Hayes, 2004) on national systems of innovation and national innovation policy. Few papers have offered an evaluation for innovation efficiency. This study utilizes the data from EIS and applies Grey Relational Analysis (GRA) and Data Envelopment Analysis (DEA) to evaluate the innovation efficiency for 33 countries.

VARIABLE EXPLANATION

Figure 1 displays the innovation input and output framework. Innovation input contains three factors: innovation driver, knowledge creation, and innovation and entrepreneurship. Application and intellectual property present innovation output.

Innovation input

Innovation drivers

Innovation drivers measure the structural conditions required for innovation potential, this consisted with “technology capability” means the capability of absorbing, applying, and imitating technology of products, process, and production organization. Except cumulating human capital, innovation drivers stress social learning (network population and life-long learning) (European Commission, 2005a).

Innovation drivers contain five variables such as new S&E graduates per 1000 population aged 20 - 29,

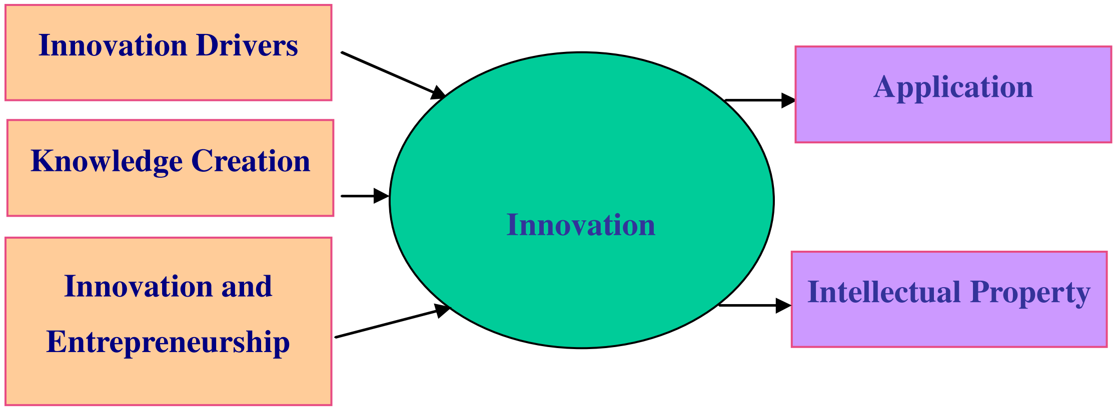

Figure 1. Innovation input and output framework.

population with tertiary education per 100 population aged 25 - 64, broadband penetration rate (number of broadband lines per 100 population), participation in life-long learning per 100 population aged 25 - 64), and youth education attainment level (% of population aged 20-24 having completed at least upper secondary education) (European Commission, 2005b).

Knowledge creation

Knowledge creation measures the investments on human factors and on R&D activities, considered as the key elements for a successful knowledge-based economy. Knowledge creation includes five variables: public R&D expenditures (% of GDP), Business Share of medium-high tech and high-tech R&D (% of manufacturing R&D expenditures), Business R&D expenditures (% of GDP), Share of enterprises receiving public funding for innovation, and university R&D expenditures financed by business sector (Alam, 2009a).

Innovation and entrepreneurship

Innovation and entrepreneurship measures the efforts towards innovation at the microeconomic level, which contains six variables: SMEs innovating in house (% of SMEs), innovative SMEs cooperating with others (% of SMEs), innovation expenditures (% of turnover), early-stage venture capital (% of GDP), ICT expenditures (% of GDP), and SMEs using non technological change (% of SMEs) (European Commission, 2005a).

Application

Application measures the performance, expressed in terms of labour and business activities, and their value added in innovative sectors. Application includes five variables: employment in high-tech services (% of total workforce), exports of high technology products as a share of total exports, sales of new-to-market products (% of turnover), sales of new-to-firm not new-to-market products (% of turnover), and employment in medium-high and high-tech manufacturing (% of total workforce) (European Commission, 2005b).

Intellectual property

Intellectual property measures the achieved results in terms of successful know how especially referred to high-tech sectors. This factor contains five variables: 5.1 EPO patents per million population, 5.2 USPTO patents per million population, 5.3 triadic patent families per million population, 5.4 number of new community trademarks per million population, and 5.5 number of new community designs per million population (Alam and Hoque, 2010).

Research questions

How to develop an efficient national innovation system is key challenge for every country. This research aims to answer the following research questions:

1. What are the input factors of the national innovation system?
2. What are the output factors of the national innovation system?
3. How to evaluate the efficiency of the national innovation system?
4. What are the innovation policies in those best performance countries?

This research believes that the answers of these questions will be able to provide some suggestions and guidelines for policy makers of some countries. However, the main purpose of this paper is to illuminate the insights of problems with a view to that identifying of problems will inspire to conduct further researches in national innovation system area and the further researches might be able to provide better solution in future.

METHODOLOGY

Grey relational analysis

Deng (1988) pioneered Grey system theory in 1988. Grey system theory is concerned with solving problems that involve uncertainty or systems with incomplete information. Using system relational analysis, model construction, forecasting, or decision analysis, grey system theory can effectively resolve various problems that involve uncertainty, multiple variables or discrete data.

GRA has no requirements regarding sample size or specific probability assumptions, and involves simple calculations since it is based on developmental data trends. GRA primarily uses discrete measurements to evaluate the distance between two sequences and explore the extent of their relationship (Deng, 1988). The original numerals are transformed (or normalized) into numerals between zero and one. That is, the transformed numerals are scale-invariant. The sequence of the transformed numerals is a comparative sequence.

The calculation process for GRA is expressed as follows (Deng, 1988).

Let ***X*** be a factor set of Grey relation, $X=\{\mathbf{x}_0,\mathbf{x}_1,...,\mathbf{x}_m\}$, where $\mathbf{x}_0 \in X$ denotes the referential sequence; $\mathbf{x}_i \in X$ represents the comparative sequence, and *i*= 1, …, *m*. Both $\mathbf{x}_0$ and $\mathbf{x}_i$ include *n* elements and can be expressed as follows.

$$\mathbf{x}_0=(x_0(1),x_0(2),...,x_0(k),...,x_0(n)) \quad (4)$$

$$\mathbf{x}_i=(x_i(1),x_i(2),...,x_i(k),...,x_i(n)) \quad (5)$$

where *i* = 1, …, *m*; *k* = 1, …, *n*; $n \in N$, and $x_0(k)$ and $x_i(k)$ are the numbers of referential sequences and comparative sequences at point *k*, respectively. In practical applications, the referential sequence can be an ideal objective and the comparative sequences are alternatives. The best alternative corresponds to the largest degree of Grey relation. If the grey relational coefficient (GRC) of the referential sequences and comparative sequences at point *k* is $\gamma(x_0(k),x_i(k))$, then the degree of grey relation for $\mathbf{x}_0$ and $\mathbf{x}_i$ will be $\gamma(\mathbf{x}_0,\mathbf{x}_i)$ when the following four prerequisites satisfy:

1. Normal interval:

$$0<\gamma(\mathbf{x}_0,\mathbf{x}_i)\le 1,$$
$$\gamma(\mathbf{x}_0,\mathbf{x}_i)=1 \Leftrightarrow \mathbf{x}_0=\mathbf{x}_i,$$
$$\gamma(\mathbf{x}_0,\mathbf{x}_i)=0 \Leftrightarrow \mathbf{x}_0,\mathbf{x}_i \in \phi.$$

2. Dual symmetry:

$$\mathbf{x},\mathbf{y}\in \mathbf{X},$$
$$r(\mathbf{x},\mathbf{y})=r(\mathbf{y},\mathbf{x}) \Leftrightarrow \mathbf{X}=\{\mathbf{x},\mathbf{y}\}$$

3. Wholeness:

$$\mathbf{x}_i,\mathbf{x}_j\in \mathbf{X},$$
$$\gamma(\mathbf{x}_i,\mathbf{x}_j) \overset{often}{\neq} \gamma(\mathbf{x}_j,\mathbf{x}_i).$$

4. Approachability:

With $|x_0(k)-x_i(k)|$ getting larger, $\gamma(x_0(k),x_i(k))$ becomes smaller. The essential condition and quantitative model for grey relation are produced based on the above four prerequisites. The GRC of the referential sequences and comparative sequences at point *k* is expressed as follows:

$$\gamma(x_0(k),x_i(k))=\frac{\min\limits_{i\in I}.\min\limits_{k}.|x_0(k)-x_i(k)|+\zeta\max\limits_{i\in I}.\max\limits_{k}.|x_0(k)-x_i(k)|}{|x_0(k)-x_i(k)|+\zeta\max\limits_{i\in I}.\max\limits_{k}.|x_0(k)-x_i(k)|} \quad (6)$$

where ζ is a distinguished coefficient with a value between zero and one. The ζcan be adjusted to suit practical requirements and it is normally set at 0.5.

The grey relational grade (GRG) stands for the degree of grey relation between the referential sequences and comparative sequences is defined as a GRC mean and can be expressed as follows.

$$\gamma(\mathbf{x}_0,\mathbf{x}_i)=\frac{1}{n}\sum_{i=1}^{n}\gamma(x_0(k),x_i(k)) \quad (7)$$

A larger GRG corresponds to a stronger degree of grey relation between the comparative and referential sequences.

Data envelopment analyses

Data envelopment analysis is used to exam the relative performance of organizational units or countries. As part of analysis the inputs (resources) and outputs (performances) associated with the process are identified. These variables are classified as controllable and uncontrollable variables. A ratio of output over input is calculated across all of the variables, which results in efficiency score for each of units being analyzed. The comparison is peer based and so the potential improvements identified for inefficient units should be realistic and achievable.DEA generalized the 1957 Farrell (1957) single-input-single-output technical efficiency measure to the multiple-input-multiple-output case. The terms “data envelopment analysis (DEA)” and “decision making unit (DMU)” were first coined in 1978 by Charnes et al., (1978). The idea was to build a virtual input and virtual output which are weighted sums of the actual inputs and outputs, respectively. Letting $x_{i,k}$ be input *i* (*i* = 1,2,…,7), and $y_{j,k}$ be output *j* (*j* =1,2), for the k^{th} DMU, a virtual input U_k can be built such that $U_k=\sum_i \alpha_i x_{i,k}$ and a virtual output $Y_k=\sum_j \beta_j y_{j,k}$

Where: and α_J and β_J are the weights of the inputs and outputs, respectively. An efficiency equation can be constructed in the usual sense. We define the efficiency

$$E_k=\frac{Y_k}{U_k}$$

which is the same type of output to input ratio as for single-input-single-output case. Thus, the problem of determining the innovation efficiencies of these 33 countries becomes a problem of determining the weight.

To do this, let E_m be the efficiency index of the m^{th} DMU. The following fractional program is developed

Subject to: $\frac{\sum_j \beta_j y_{j,k}}{\sum_i \alpha_i x_{i,k}} \le 1 \forall k$, $\alpha_i, \beta_j \ge 0 \forall i, j$

$$\frac{\sum_j \beta_j y_{j,k}}{\sum_i \alpha_i x_{i,k}} \le 1 \forall k \Leftrightarrow \sum_j \beta_j y_{j,k} \le \sum_i \alpha_i x_{i,k} \forall k$$

and the following constraint added:

$$\sum_i \alpha_i x_{i,m} = 1,$$

Then the fractional program becomes the following linear program:
Maximize:

$$E_m = \sum_j \beta_j y_{j,m}$$

Subject to: $\sum_i \alpha_i x_{i,m} = 1$,

$$\sum_j \beta_j y_{j,k} \le \sum_i \alpha_i x_{i,k} \forall k,$$

$$\alpha_i, \beta_j \ge 0 \forall i, j$$

With further manipulation the linear program becomes:
Maximize Θ
Subject to: $\sum_i \lambda_i X_i \le X_m$,

$$\sum_i \lambda_i Y_i \ge \Theta Y_m,$$

$$\lambda_i \ge 0 \forall i,$$

Where, Θ = relative efficiency rating for DMU *m*, X_j= vector of input into DMU*i*, Y_i= vector of output into DMU*i*, X_m= vector of inputs into DMU being evaluated, Y_m= vector of outputs into DMU being evaluated and λ_i = weight of DMU*i* .

The linear program is known as the output oriented Charnes, Cooper, and Rhodes (1978) (CCR) model. The dual of this linear pro-gram gives the input oriented CCR model as shown in:

Minimize: Φ,
Subject to: $\sum_i \lambda_i X_i \le \Phi X_m$

$$\sum_i \lambda_i Y_i \ge Y_m,$$

$$\lambda_i \ge 0 \forall i,$$

Where, Φ =relative efficiency rating for DMU*m*.

RESULTS

The first step in data envelopment analysis is the determination of the inputs and outputs. In this study, the following parameters were chosen as input: Innovation driver, knowledge creation, innovation and entrepreneurship. The two outputs are application and intellectual property. Table 1 presented Grey relational grade for innovation driver and five variables were chosen. SE (Sweden) ranked highest in innovation driver among 33 countries. The ranks of gray relational grade in innovation drive and knowledge creation are as Table 1.

Table 2 shows grey relational grade for innovation and entrepreneurship and six variables. CH (Switzerland) was ranked first in innovation and entrepreneurship. The other 32 countries were ranked as Table 2 in grey relational grade for innovation and entrepreneurship. Table 2 Grey relational grade for application and five variables in this factor. FI (Finland) was ranked first one in Grey relational grade for application and other countries were ranked as Table 2. The decline in business R&D could therefore be linked to the collapse of the dotcom bubble and high technology stocks. However, the decline in business R&D could also be due to other trends, such as a shift in R&D abroad combined with a decline in national competitiveness for research, that are worth following closely over the next few years.

Table 3 depicted Grey relational grade for intellectual property and contained five variables. CH (Switzerland) was ranked the first and other countries were ranked as Table 3 in Grey relational grade for intellectual property.

Table 4 also listed efficiency score applying DEA and obtained from innovation input factors and innovation output factors. The first country was DK (Denmark), DE (German), IE (Ireland), LU (Luxemburg), MT (Malta), and CH (Switzerland). Others were ranked as Table 3. In Table 3 F1 represents the gray relation grade of Innovation Driver, F2 means the gray relation grade of Knowledge Creation, F3 is the gray relation grade of Innovation and Entrepreneurship, F4 is Application, and F5 is Intellectual Property.

DISCUSSION

This study utilized the data from EIS and applied Grey Relational Analysis (GRA) and Data Envelopment Analysis (DEA) to evaluate the innovation efficiency for 33 countries. This study also provided cross-national

Table 1. Grey relational grade for innovation driver and knowledge creative.

Na	Gray Relational Coefficient					GRG	R	Gray Relational Coefficient					GRG	R
	1.1	1.2	1.3	1.4	1.5			2.1	2.2	2.3	2.4	2.5		
BE	0.46	0.59	0.83	0.40	0.64	0.58	9	0.45	0.49	0.74	0.55	0.70	0.59	7
CZ	0.38	0.36	0.34	0.37	0.85	0.46	20	0.41	0.39	0.78	0.37	0.34	0.46	22
DK	0.51	0.67	1	0.68	0.55	0.68	2	0.52	0.51	0.81	0.37	0.38	0.52	15
DE	0.42	0.50	0.46	0.37	0.51	0.45	22	0.52	0.51	1	0.57	0.67	0.65	3
EE	0.41	0.63	0.49	0.37	0.65	0.51	13	0.43	0.35	0.55	0.36	0.48	0.43	26
EL	0.42	0.41	0.33	0.35	0.64	0.43	24	0.40	0.34	0.35	0.47	0.46	0.41	30
ES	0.49	0.52	0.46	0.36	0.42	0.45	23	0.41	0.37	0.67	0.47	0.52	0.49	18
FR	0.87	0.48	0.51	0.38	0.61	0.57	10	0.55	0.46	0.84	0.51	0.38	0.55	12
IE	1	0.54	0.36	0.38	0.70	0.60	8	0.38	0.39	0.77	0.37	0.40	0.46	21
IT	0.39	0.35	0.45	0.36	0.48	0.40	28	0.45	0.37	0.99	0.68	0.39	0.58	9
CY	0.36	0.60	0.36	0.39	0.61	0.46	18	0.36	0.33	0.52	0.53	0.46	0.44	25
LV	0.41	0.42	0.35	0.39	0.56	0.43	25	0.36	0.34	0.35	0.35	0.40	0.36	33
LT	0.59	0.48	0.37	0.36	0.72	0.51	15	0.44	0.34	0.56	0.39	0.39	0.42	29
LU	0.33	0.40	0.44	0.37	0.48	0.40	29	0.33	0.49	0.33	0.44	0.64	0.45	23
HU	0.36	0.39	0.37	0.36	0.67	0.43	27	0.47	0.36	0.87	0.44	0.40	0.51	16
MT	0.34	0.33	0.39	0.36	0.33	0.35	33	0.40	0.33	0.54	0.40	0.46	0.43	28
NL	0.39	0.53	0.90	0.47	0.52	0.56	11	0.53	0.42	0.79	0.67	0.47	0.58	8
AT	0.41	0.40	0.53	0.42	0.70	0.49	17	0.48	0.44	0.73	1	0.35	0.60	4
PL	0.41	0.37	0.34	0.36	0.80	0.46	21	0.41	0.34	0.70	0.33	0.45	0.44	24
PT	0.39	0.35	0.46	0.36	0.34	0.38	32	0.43	0.35	0.61	0.63	0.34	0.47	20
SI	0.42	0.42	0.40	0.49	0.81	0.51	14	0.46	0.40	0.76	0.38	0.47	0.49	17
SK	0.41	0.36	0.34	0.36	0.86	0.46	19	0.35	0.36	0.63	0.35	0.33	0.40	31
FI	0.69	0.71	0.63	0.61	0.69	0.66	33	0.69	0.64	0.82	0.95	0.46	0.71	1
SE	0.52	0.55	0.69	1	0.73	0.70	1	0.63	1	0.99	0.48	0.43	0.70	2
UK	0.82	0.63	0.48	0.54	0.56	0.61	7	0.46	0.44	0.94	0.38	0.44	0.53	14
BG	0.42	0.46	0.37	0.33	0.55	0.43	26	0.39	0.34	0.65	0.34	0.44	0.43	27
RO	0.37	0.34	0.38	0.34	0.50	0.39	31	0.34	0.35	0.45	0.35	0.44	0.38	32
TR	0.38	0.34	0.38	0.36	0.54	0.40	30	0.41	0.34	0.59	0.40	1.00	0.55	11
CH	0.41	0.55	0.58	0.62	0.51	0.53	12	0.49	0.54	0.68	0.57	0.40	0.53	13
IS	0.44	0.54	0.55	0.60	0.35	0.50	16	1	0.51	0.35	0.39	0.61	0.57	10
NO	0.43	0.65	0.45	0.51	1	0.61	6	0.49	0.41	0.59	0.45	0.43	0.48	19
US	0.46	1	0.57	0.51	0.51	0.61	5	0.52	0.53	0.93	0.56	0.42	0.59	5
JP	0.53	0.89	0.66	0.58	0.52	0.63	4	0.53	0.62	0.81	0.63	0.36	0.59	6

1.1 denotes new S&E graduates per 1000 population aged 20-29. 1.2 denotes population with tertiary education per 100 population aged 25-64. 1.3 denotes broadband penetration rate (number of broadband lines per 100 population). 1.4 denotes participation in life-long learning per 100 population aged 25-64). 1.5 denotes youth education attainment level (% of population aged 20-24 having completed at least upper secondary education). 2.1 denotes public R&D expenditures (% of GDP). 2.2 denotes Business Share of medium-hightech and high-tech R&D (% of manufacturing R&D expenditures). 2.3 denotes business R&D expenditures (% of GDP). 2.4 denotes share of enterprises receiving public funding for innovation. 2.5 denotes university R&D expenditures financed by business sector.

innovation policy analysis for leading innovation efficient countries. Denmark, German, Ireland, Luxemburg, Malta, and Switzerland were the most innovation efficiency countries among 33 countries in this study. DK (Denmark), DE (German), IE (Ireland), LU (Luxemburg), MT (Malta), and CH (Switzerland) were most innovation efficiency countries in this study. In particular for high-tech exports, the high scores for Luxemburg and Malta are most likely reason is industrial specialization. Notable declines in business R&D have occurred in Germany and and Ireland, while remaining stable in Luxembourg and only increasing in Denmark. For those countries with a decline, the peak year for best performance in business R&D ranges between 1998 and 2003.

Innovation leaders are here simply defined as the best three ranking countries as the way suggested by (Alam, 2009b). Germany is leading in about 15 sectors each and overall leaders in the manufacturing sector and services. Despite their above average EIS 2005 innovation performance, Denmark shows a below average representation

Table 2. Grey relational grade for innovation and entrepreneurship and application.

Na	Gray Relational Coefficient						GRG	R	Gray Relational Coefficient					GRG	R
	3.1	3.2	3.3	3.4	3.5	3.6			4.1	4.2	4.3	4.4	4.5		
BE	0.56	0.46	0.67	0.43	0.47	0.54	0.52	10	0.65	0.36	0.42	0.53	0.51	0.50	13
CZ	0.41	0.39	0.41	0.34	0.64	0.47	0.44	24	0.50	0.38	0.48	0.40	0.68	0.49	14
DK	0.36	0.68	0.35	0.69	0.49	0.40	0.49	16	0.83	0.39	0.46	0.52	0.50	0.54	8
DE	0.71	0.45	0.67	0.40	0.45	0.74	0.57	5	0.53	0.40	0.45	1.00	1.00	0.68	2
EE	0.54	0.50	0.44	0.34	0.74	0.58	0.53	9	0.40	0.37	0.41	0.38	0.39	0.39	28
EL	0.36	0.39	0.54	0.36	0.39	0.65	0.45	22	0.35	0.36	0.37	0.43	0.35	0.37	32
ES	0.41	0.34	0.42	0.37	0.39	0.52	0.41	32	0.40	0.35	0.52	0.63	0.45	0.47	15
FR	0.45	0.45	0.62	0.44	0.43	0.38	0.46	20	0.69	0.43	0.44	0.48	0.52	0.51	11
IE	0.39	0.45	0.33	0.41	0.37	0.48	0.41	33	0.65	0.51	0.42	0.44	0.51	0.51	12
IT	0.47	0.34	0.52	0.35	0.40	0.54	0.44	28	0.47	0.35	0.58	0.60	0.57	0.51	10
CY	0.33	0.48	0.44	0.33	0.49	0.57	0.44	25	0.37	0.34	0.34	0.36	0.33	0.35	33
LV	0.35	0.35	0.65	0.34	0.90	0.45	0.51	14	0.40	0.34	0.40	0.40	0.35	0.38	31
LT	0.39	0.53	0.48	0.34	0.48	0.42	0.44	27	0.35	0.34	0.40	0.46	0.38	0.39	29
LU	0.58	0.37	0.43	0.48	0.52	0.92	0.55	7	0.47	0.51	0.36	0.40	0.34	0.41	24
HU	0.35	0.50	0.44	0.34	0.65	0.41	0.45	23	0.50	0.44	0.34	0.37	0.64	0.46	19
MT	0.33	0.33	0.51	0.33	0.53	0.58	0.44	29	0.47	1.00	0.40	0.39	0.50	0.55	6
NL	0.51	0.46	0.46	0.43	0.51	0.46	0.47	19	0.59	0.42	0.37	0.50	0.41	0.46	18
AT	0.53	0.44	0.49	0.37	0.46	0.64	0.49	17	0.53	0.40	0.41	0.52	0.50	0.47	16
PL	0.34	0.37	0.49	0.35	0.95	0.50	0.50	13	0.40	0.34	0.40	0.40	0.50	0.41	25
PT	0.53	0.40	0.65	0.42	0.49	0.56	0.51	12	0.33	0.36	0.65	0.57	0.38	0.46	20
SI	0.37	0.42	0.43	0.40	0.47	0.56	0.44	26	0.44	0.35	0.43	0.37	0.70	0.46	21
SK	0.34	0.35	0.80	0.34	0.46	0.33	0.44	30	0.42	0.34	0.46	0.39	0.62	0.45	22
FI	0.55	1.00	0.62	0.72	0.49	0.53	0.65	2	0.91	0.43	1.00	0.65	0.54	0.71	1
SE	0.52	0.57	0.46	1.00	0.57	0.50	0.61	3	1.00	0.39	0.53	0.83	0.55	0.66	3
UK	0.40	0.42	0.49	0.48	0.58	0.50	0.48	18	0.79	0.44	0.35	0.57	0.51	0.53	9
BG	0.34	0.41	0.37	0.34	1.00	0.53	0.50	15	0.44	0.34	0.36	0.36	0.43	0.39	30
RO	0.35	0.34	0.43	0.34	0.66	1.00	0.52	11	0.33	0.34	0.51	0.33	0.46	0.39	27
TR	0.34	0.34	0.51	0.34	0.33	0.70	0.43	31	0.41	0.33	0.40	0.40	0.46	0.40	26
CH	1.00	0.48	1.00	0.53	0.48	0.48	0.66	1	0.68	0.41	0.53	0.79	0.55	0.59	4
IS	0.72	0.54	0.48	0.45	0.54	0.59	0.55	6	0.94	0.33	0.33	0.35	0.35	0.46	17
NO	0.45	0.54	0.42	0.45	0.44	0.46	0.46	21	0.63	0.34	0.35	0.40	0.43	0.43	23
US	0.52	0.61	0.45	0.56	0.81	0.51	0.58	4	0.69	0.48	0.46	0.55	0.57	0.55	7
JP	0.61	0.58	0.45	0.60	0.59	0.45	0.55	8	0.85	0.45	0.48	0.62	0.53	0.59	5

3.1 denotes SMEs innovating inhouse (% of SMEs). 3.2 denotes innovative SMEs cooperating with others (% of SMEs). 3.3 denotes innovation expenditures (% of turnover). 3.4 denotes early-stage venture capital (% of GDP). 3.5 denotes ICT expenditures (% of GDP), and 3.6 SMEs using nontechnological change (% of SMEs). 4.1 denotes employment in high-tech services (% of total workforce). 4.2 denotes exports of high technology products as a share of total exports. 4.3 denotes sales of new-to-market products (% of turnover). 4.4 denotes sales of new-to-firm not new-to-market products (% of turnover). 4.5 denotes employment in medium-high and high-tech manufacturing (% of total workforce).

in sector leadership. Malta is the country with the highest proportion of pro-innovation citizens.

Germany is least ready to embrace innovation. Malta with the highest proportion of pro-innovation citizens is characteristic as these countries all have better results for the output indicators of the EIS than for the input indicators if compared with the European trend.

Denmark

DK (Denmark) need improve knowledge creation. Insufficient innovation and R&D input in public sector and university. Innovation policy supervised by technology and innovation department and assisted by associations or foundation of R&D advisory and financing system in Denmark. Different types of project managed by different public organization. Researcher oriented project is bottom-up management from The Danish Council for Independent Research to The Danish National Research Foundation. Policy oriented is top-down management from The Danish Council for Strategic Research to The High Technology Foundation. Denmark need improve

Table 3. Grey relational grades for intellectual property.

Country	Gray relational coefficient					Gray relational grade	Rank
	5.1	5.2	5.3	5.4	5.5		
BE	0.487222	0.394615	0.428953	0.367965	0.482857	0.432322	11
CZ	0.340656	0.336052	0.335188	0.343891	0.345301	0.340218	24
DK	0.616322	0.408998	0.478175	0.397324	1	0.580164	6
DE	0.936393	0.478443	0.6025	0.384812	0.654676	0.611365	4
EE	0.339166	0.3352	0.336436	0.341868	0.339066	0.338347	25
EL	0.338672	0.33462	0.33449	0.342965	0.334464	0.337042	26
ES	0.351998	0.339227	0.339437	0.394203	0.442408	0.373454	18
FR	0.486001	0.392275	0.432675	0.364041	0.435407	0.42208	12
IE	0.412119	0.358892	0.360599	0.396658	0.437338	0.393121	16
IT	0.396117	0.357158	0.364048	0.368333	0.582759	0.413683	13
CY	0.339959	0.334799	0.335889	0.386248	0.336462	0.346671	20
LV	0.337101	0.333378	0.335655	0.334377	0.338968	0.335896	29
LT	0.33458	0.333555	0.333949	0.335121	0.340432	0.335527	30
LU	0.58501	0.423398	0.439514	1	0.600203	0.609625	5
HU	0.346337	0.336863	0.340395	0.337615	0.343795	0.341001	23
MT	0.345822	0.335066	0.334955	0.361695	0.344196	0.344347	22
NL	0.825994	0.412151	0.506657	0.391176	0.578484	0.542892	8
AT	0.532022	0.389539	0.42592	0.408449	0.64539	0.480264	10
PL	0.334676	0.33351	0.333872	0.33872	0.338968	0.335949	27
PT	0.335836	0.334175	0.335032	0.352831	0.365801	0.344735	21
SI	0.357846	0.339547	0.342087	0.348671	0.362995	0.350229	19
SK	0.335836	0.33462	0.334955	0.334377	0.339943	0.335946	28
FI	0.995719	0.513221	0.834873	0.368292	0.480699	0.638561	3
SE	1	0.569116	0.79538	0.382457	0.47491	0.644372	2
UK	0.459321	0.388635	0.411966	0.379912	0.428313	0.413629	14
BG	0.335352	0.33382	0.333333	0.333333	0.334181	0.334004	31
RO	0.333333	0.333333	0.33341	0.333669	0.333333	0.333416	33
TR	0.333429	0.333378	0.333333	0.333636	0.335508	0.333857	32
CH	0.59641	0.474738	1	0.421444	0.732054	0.644929	1
IS	0.450077	0.382252	0.368126	0.35771	0.353874	0.382408	17
NO	0.462978	0.379425	0.393898	0.342717	0.386601	0.393124	15
US	0.497434	1	0.509514	0.348304	0.350311	0.541112	9
JP	0.517579	0.845869	0.810538	0.337615	0.351247	0.57257	7

5.1 denote EPO patents per million population; 5.2 denote USPTO patents per million population; 5.3 denote triadic patent families per million population; 5.4 denote number of new community trademarks per million population; 5.5 denote number of new community designs per million population.

commercialization and innovation in entrepreneur stage. University played important role in innovation frontier and few support from government and public research organization.

Germany

German Research Foundation serves all branches of science and the humanities by financing research projects and facilitating cooperation among researchers. It devotes particular attention to the education and advancement of young researchers, promotes equality between men and women in the scientific and academic communities, and advises parliaments and public authorities on scientific matters and fosters relations with the private sector and between scientists and academics at home and abroad (Zach, 2006). Germany establishes efficient R&D and innovation encouragement mechanism by improving social problems and builds friendly and international comparative innovation framework: from e government to IT construction and apply to education and life. Emphasizing equal usage and security legal system and stressing public science research and technology transformation increases research efficiency from public organization and improves commercialization for science

Table 4. Grey relational grade and efficiency score applying DEA.

Country	Input			Output		Efficiency Score (%)	Rank
	Innovation Driver	Knowledge Creation	Innovation and Entrepreneurship	Application	Intellectual property		
BE	0.584045	0.58632	0.524428	0.496046	0.432322	79.20	25
CZ	0.458281	0.458531	0.441859	0.490676	0.340218	88.77	17
DK	0.681381	0.515544	0.493367	0.541359	0.580164	100.00	1
DE	0.452135	0.654077	0.570184	0.675103	0.611365	100.00	1
EE	0.508344	0.431129	0.526393	0.388548	0.338347	75.86	30
EL	0.42946	0.406531	0.449369	0.372833	0.337042	78.98	26
ES	0.449352	0.488193	0.407123	0.472984	0.373454	94.58	10
FR	0.569331	0.547148	0.463185	0.511647	0.42208	90.31	13
IE	0.595167	0.461683	0.405352	0.505598	0.393121	100.00	1
IT	0.404357	0.575908	0.438631	0.513965	0.413683	96.33	8
CY	0.464478	0.440548	0.441482	0.348891	0.346671	73.52	32
LV	0.427646	0.360044	0.507299	0.377926	0.335896	88.88	16
LT	0.505472	0.421033	0.439968	0.385414	0.335527	78.73	27
LU	0.403126	0.446514	0.549548	0.41455	0.609625	100.00	1
HU	0.425883	0.50646	0.447984	0.458776	0.341001	82.94	22
MT	0.351377	0.426969	0.437863	0.553081	0.344347	100.00	1
NL	0.559474	0.576987	0.472543	0.459354	0.542892	99.41	7
AT	0.491274	0.599076	0.48819	0.471211	0.480264	88.14	18
PL	0.456913	0.444137	0.500083	0.407154	0.335949	75.99	29
PT	0.378755	0.470733	0.510483	0.458445	0.344735	81.40	23
SI	0.505938	0.493873	0.440507	0.457309	0.350229	83.93	21
SK	0.462774	0.402022	0.436006	0.44663	0.335946	89.94	14
FI	0.662974	0.711032	0.653046	0.706419	0.638561	92.38	12
SE	0.696427	0.703928	0.605838	0.659273	0.644372	95.05	9
UK	0.606372	0.530636	0.47929	0.530977	0.413629	89.74	15
BG	0.426376	0.430114	0.496506	0.385157	0.334004	75.28	31
RO	0.386335	0.383601	0.518868	0.394633	0.333416	85.84	20
TR	0.397922	0.548183	0.426231	0.401186	0.333857	77.83	28
CH	0.533201	0.534564	0.6616	0.591864	0.644929	100.00	1
IS	0.496378	0.572314	0.554169	0.461288	0.382408	71.01	33
NO	0.607795	0.476547	0.461081	0.430396	0.393124	80.88	24
US	0.609563	0.591456	0.577551	0.55155	0.541112	87.03	19
JP	0.634323	0.590346	0.548512	0.587374	0.57257	93.91	11

application. Identifying, mobilizing, and publicizing the innovation potential of this country motivates Germany as technology and innovation leading country. Germany simplifies taxation system, decreases business tax loading, and reduces government paper process. Vocational education, training, innovation projects are proposed by public research collaborate with industry improve education and science system to resolve insufficient human resource problem and improve qualify professional personnel.

Germany uses financial support to motivate innovation activities and innovation policy is linking public and private research organization, supporting industrial innovation activities, especially in supporting SME development to enhance national competitive, growth, and employment. Germany's excellence initiative strengthen Germany's universities and make them more visible and attractive internationally as better faculty, better students, and better research. Support potential young researchers and industry collaborated research team by financial incentives to establish local innovation network for integrating profession and technology. International co-operation plays an increasingly important role in research policy, more cooperation with other research funding organizations. Providing capital and profession consultant service, German encourages professional development to publish R&D results and commercialization planning of early stage. Buttom-up, open planning competition, and short-term research financial support encourages long-term innovation in Germany.

Germany's weak performance on Innovation drivers might thus hamper the effect of increased efforts in other key dimensions on the overall innovative performance of the country.

Ireland

Ireland operates a system in which Government Departments are responsible for policy and executive actions are delegated to statutory agencies which are governed by independent boards. In practice, there is considerable interchange between departments and the agencies in question and it is normal practice to have at least one senior civil servant on the board of the agencies (Costello, 2006). Especially, Forfás is the most important science and technology policy organization. National competitive committee also provides science and technology policy advises for government. Ireland need enhance innovation input and output, especially in innovation drive, knowledge creation, innovation and entrepreneurship, and intellectual property.

Luxemburg

In particular for high-tech exports the high scores for Luxemburg are most likely due to industrial specialization. Based on Summary Innovation Index (SII), Luxembourg belongs to the group of average performance countries, but outstanding performance in innovation efficiency in this study.

Malta

In particular for high-tech exports the high scores for Malta are most likely due to industrial specialization. Malta is the group of catching up countries in Summary Innovation Index (SII), but outstanding performance in innovation efficiency in this study.

Switzerland

Swiss National Science Foundation founded in 1952 under private law with autonomous scientific executive body and research body of the Swiss Federation. SNSF supports scientific research which is the largest Swiss institution for research support with budget 479 MCHF in 2006. SNSF promotes scientific research, supports young scientists, enables research stays abroad, promotes international co-operation, and strengthens the position of women in science (Ott, 2006). Switzerland made up the group of leading countries in Summary Innovation Index (SII) and also outperform in innovation efficiency of this study. Switzerland is the example of country showing much better transformation of their assets into innovation success and to be one of European innovation leaders but performed worse in knowledge creation.

Application

Building up the areas of strengths could have a positive influence on the weaknesses, as when a country traces their innovation performance following these indicators. This might not occur if very poor performance in innovation and entrepreneurship acts as a barrier to an improvement in technology similar advocacy made by (Alam et al., 2010). Given equal costs, policy would be more effective in improving overall innovation performance by concentrating on improving areas of weakness rather than on making further improvements to areas of strength. It also suggests that for countries where innovation performance is high, marginal gains are optimized when all dimensions of innovation are addressed together. This analysis could be taken into consideration when discussing policy orientations. In Taiwan, government tried hard to trace these innovation indicators as instrument for improving national policy and provide better environment for business and people.

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