Interaction in R&D networks among university, large enterprises, SMEs, venture firms, and government: Evidence from Korea

YoungJun Kim, YoungHoon Lee

고려대학교 기술경영전문대학원
Graduate School of Management of Technology
KOREA UNIVERSITY

1.1. National R&D Program

- Given that investment in R&D is one of the most important factors in enhancing technological progress and economic growth,
  many countries have steadily increased investment in national R&D programs.

- National R&D program is the most active policy funded by the government to increase the innovative capacities of R&D actors and to stimulate the R&D of universities, industries(large enterprises, SMEs, venture firms), and governmental R&D centers.

Table. 1. The budgets for national R&D programs ('04 ~ '13)

Unit: million U.S. dollars

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013
Korea	5,326	6,578	7,571	8,759	8,481	8,325	10,343	11,771	12,536	13,704
U. S.	126,271	131,259	136,019	141,890	144,391	164,292	148,962	144,379	143,737	133,515
Japan	33,351	32,462	30,734	29,819	34,548	38,088	40,886	45,715	46,279	36,751
Germany	21,038	21,415	22,088	25,596	28,845	30,160	30,482	33,007	30,881	33,346

Source : OECD (2014), "Main Science and Technology Indicators"; KISTEP (2014), "OECD 자료로 살펴본 주요국 정부연구개발예산 현황"

KOREA UNIVERSITY

1.2. National Competitiveness of Korea

Table. 2. Representative R&D indicators' rankings of Korea among 60 countries (2010–2014)

	Criteria10	'10	'11	'12	'13	'14	comparison to last year
R&D inputs	Total expenditure on R&D	7	7	7	7	**6**	↑1
	Total expenditure on R&D (Percentage of GDP)	5	5	3	3	**1**	↑2
	Government's expenditure on R&D	8	6	6	5	**10**	↓5
	Government's R&D intensity	**3**	**2**	**1**	**1**	**1**	-
	Industry's expenditure on R&D	7	7	6	6	**5**	↑1
	Industry's R&D intensity	**5**	**5**	**2**	**2**	**2**	-
Quantitative outputs	Total R&D personnel nationwide	8	9	7	7	**6**	↑1
	Science and Engineering Degrees	8	8	10	10	**9**	↑1
	Scientific Articles	10	10	9	9	**9**	-
	Patent Grants				4	**4**	-
	Number of patents in force per 100,000 inhabitants				3	**4**	↓1
Qualitative outputs	Scientific research is high by international standards	23	19	21	21	**26**	↓5
	Researchers are attracted to your country	29	18	23	25	**33**	↓8
Innovation level	National Competitiveness	23	22	22	22	**26**	↓4
	Innovative capacity of firms	11	9	13	19	**28**	↓9
R&D Interactions	Laws relating to scientific research do encourage innovation	32	27	31	27	**30**	↓3
	Knowledge transfer between companies and universities	24	25	25	27	**29**	↓2
	Technology co-operation among firms	39	31	37	37	**39**	↓2

Source : OECD (2014), "Main Science and Technology Indicators"; IMD (2014), "World competitiveness yearbook"

KOREA UNIVERSITY

1.3. What is the problem ?

- Korea highly ranked quantitative outputs, but it ranked low in total competitiveness of a country and qualitative R&D outputs, even if it has the highest R&D intensity.

- Scholars argue that important knowledge-based innovations occur when universities, industries, and government R&D institutions interact (i.e., co-operate and exchange knowledge) to find a solution for common problems.
  (J.A. Schumpeter. 1939; D. Leonard-Barton. 1998; T. Barnes et al. 2002; J.P.C Marques et al 2006; I Alvarez et al 2009; F. Phillips et al. 2014).

- This interaction is known as an innovation process that includes knowledge creation and knowledge transfer.
  (P. Cooke et al. 1997).

- The innovative capacities of actors and national competitiveness are mainly affected by the interactions among institutional R&D actors.
  (Marques et al. 2006; Álvarez et al. 2009; Barnes et al. 2002).

1.3. What is the problem ?

- The empirical analysis shows that R&D network interactions such as 'knowledge transfer' and 'technology co-operation' have strong direct relationship with scientific research level, innovation capacity, and national competitiveness.

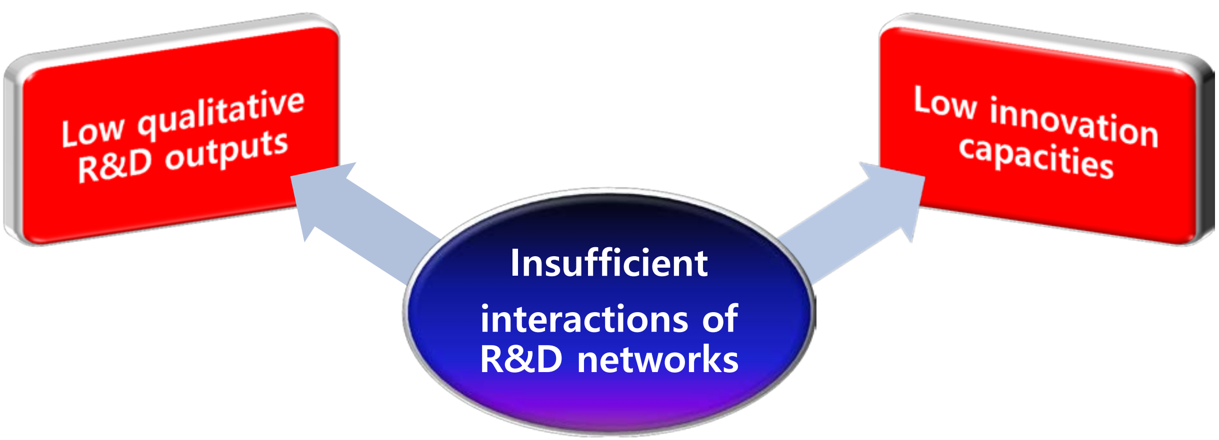
Table. 3 Correlation between R&D indicators

Variables	1	2	3	4	5	6	**7**	**8**	**9**	10
1. Government's expenditure on R&D	1									
2. Government's R&D intensity	.206	1								
3. Industry's expenditure on R&D	.981**	.194	1							
4. Industry's R&D intensity	.308*	.684**	.368**	1						
5. Scientific Articles	.977**	.194	.955**	.305*	1					
6. Patent Grants	.761**	.200	.850**	.478**	.703**	1				
7. Scientific research	.354**	.642**	.371**	.742**	.351**	.373**	1			
8. National competitiveness	.300*	.444**	.305*	.499**	.329*	.261	.790**	1		
9. Innovative capacity of firms	.341*	.598**	.343*	.678**	.339*	.301*	.901**	.837**	1	
10. **Knowledge transfer**	.256	.490**	.252	.571**	.264	.191	**.868****	**.870****	**.926****	1
11. **Technology co-operation**	.205	.493**	.214	.510**	.199	.184	**.816****	**.834****	**.833****	.874**

Note: ** significant at 1%; * significant at 5%
Sources: Elaborated on the basis of data from World competitiveness yearbook (IMD)

1.3. What is the problem ?

- Innovation can be created by dynamic interaction among university-industry-government(U-I-G), as these interactions expand knowledge resources and improve the institutional actors' capabilities to create innovative products or technologies



KOREA UNIVERSITY

2.1. Studies on interactions of R&D networks

- R&D network is the network composed of actors who interact to research and to develop the technology or the product.
  There have been many studies on the interactions of R&D networks.
  (Roessner and Bean 1994; Barnes et al. 2002; Xin 2003, etc)

➢ actors(institutional R&D actors) : universities, industries(large enterprises, SMEs, venture firms), and government R&D institutions.

- Firms have different interactions of R&D networks depending on the types of firms.

➢ Size of firms affects the R&D process as well as the co-operation failure

➢ Sustainability and prosperity of technology-based start-up firms, venture firms, are affected by the strength and composition of networks.

2.2. Triple Helix Model

- Etatistic Model : difficult to stimulate the innovation of university and industry because they were under control by the government.

- Laissez-faire Model : not able to reflect an university spin-off firms, strategic alliances among firms, government laboratories, and academic research groups.

- Triple Helix Model : for analyzing innovation in knowledge-based economy.

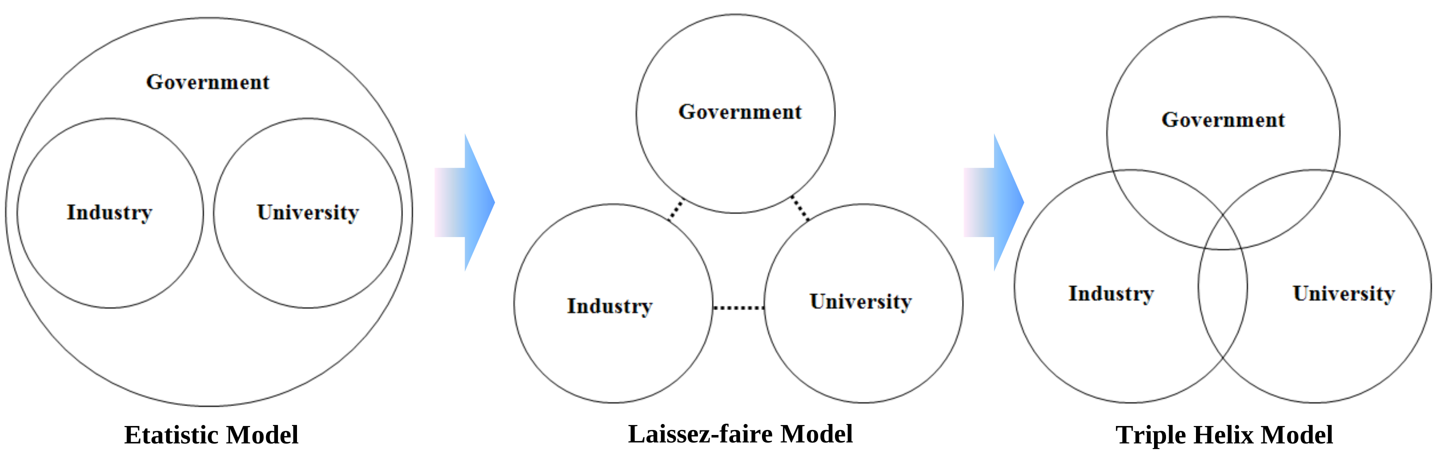


Figure. 1. The evolution of innovation systems

Source : Etzkowitz, H., and Leydesdorff, L.(2000)

KOREA UNIVERSITY

2.3. Limits of Previous Studies using Tripe Helix **(1)**

- Most of studies focused on co-authorship and co-patenting networks. However, Inzelt (2004) proposed that formal R&D projects, not co-authorships and co-patenting, can appropriately be explained by the Triple Helix model.
  (Park and Leydesdorff 2010; Leydesdorff and Sun 2009; Kwon et al. 2012; P.E. Stek et al 2014)

- Katz and Martin (1997) distinguished the co-authorship networks from the research collaboration, because the co-authorships can have the various cases.

- Co-patenting data cannot represent whole co-operation networks. In fact, only few institutions enroll their names in the inventor lists even though they co-operate officially with many other institutions.

➢ **We focus on the interaction of R&D networks in national R&D programs, which consist of formal R&D projects**

2.3. Limits of Previous Studies using Tripe Helix **(2)**

- Previous studies measured the interactions among only U-I-G, which are the traditional actors classified by the Triple Helix model,
  even if industry holds a majority of R&D activity and expenditure

- It can ignore the interaction among various types of firms(large enterprises, SMEs, venture firms) and the difference of R&D networks according to the types of firms.

➢ **We subdivide industries into three types of firms:**

large enterprises; SMEs; or venture firms

to investigate interactions in R&D networks among various types of firms.

Measuring the interactions of R&D networks

- Freeman (1995) established the information theory which can deal with information mathematically among actors.
- Based on the freeman's theory, Triple Helix indicator among university(u)-industry(i)-government(g) is proposed by Leydesdorff (2003)

Information quantity (self-information)

$$I_x = I(x) = -log_2 p(x)$$

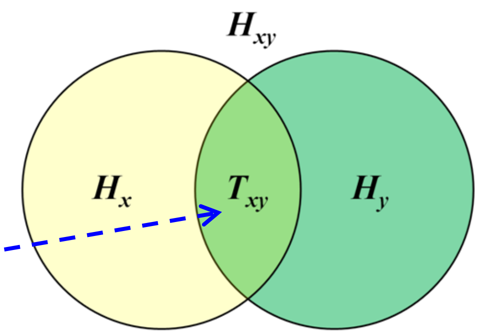
Entropy (Shannon's entropy)

$$H_x = H(x) = \sum_{x=1}^{n} p(x) I(x)$$

$$H_{xy} = H_x + H_y - T_{xy}$$

$$T_{xy} = H_x + H_y - H_{xy}$$

Mutual Information between H_x and H_y



KOREA UNIVERSITY

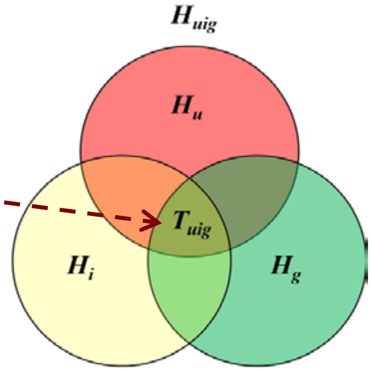
Measuring the interactions of R&D networks

- Triple Helix indicator is the trilateral mutual information among U-I-G and can have a negative or positive value.

- A negative value means that the interaction among U-I-G becomes dynamic because the Shannon entropy of each actor is reduced and each mutual information between two actors increases.

Triple Helix Indicator for 3 actors

$$T_{uig} = H_u + H_i + H_g - H_{ui} - H_{ug} - H_{ig} + H_{uig}$$



- Triple Helix indicator for quintilateral mutual information can be derived as follows

$$\begin{aligned} T_{ulsvg} = {} & H_u + H_l + H_s + H_v + H_g \\ & - H_{ul} - H_{us} - H_{uv} - H_{ug} - H_{ls} - H_{lv} - H_{lg} - H_{sv} - H_{sg} - H_{vg} \\ & + H_{uls} + H_{ulv} + H_{ulg} + H_{usv} + H_{usg} + H_{uvg} + H_{lsv} + H_{lsg} + H_{lvg} + H_{svg} \\ & - H_{ulsv} - H_{ulsg} - H_{ulvg} - H_{usgv} - H_{lsvg} + H_{ulsvg} \end{aligned}$$

National R&D programs in Korea from 1987 to 2012

- We collected valid data for the years 1987(when the industrial technology R&D program started in Korea) ~ 2012 and categorized the institutional actors as universities, industries, and government (government R&D institutions)

- The research data are 64,459 R&D networks which performed by 143,107 R&D actors for 26 years. (18.95 billion U.S. dollars are funded)

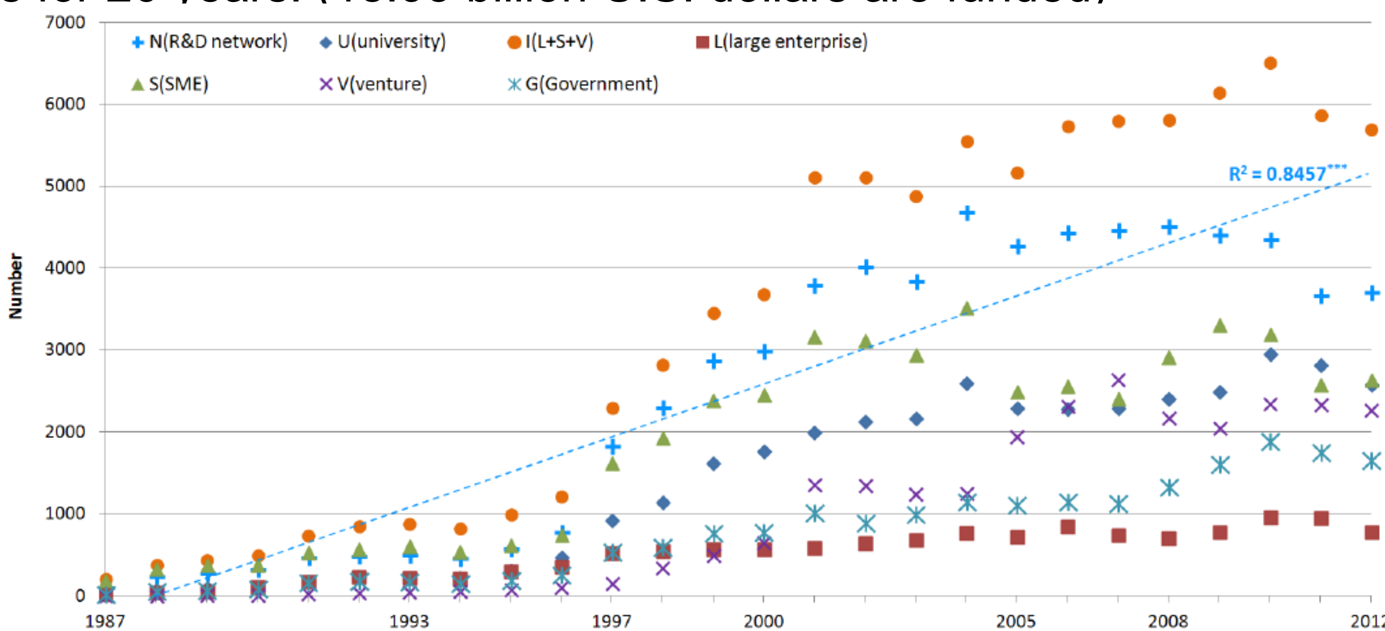


Figure. 2. Summary of Research Data

IV. Data

Table. 3. Brief history of policy enforcement for industrial technology R&D programs in Korea

Period	Year	Policy
1	1988 ~ 1992	Korean government started the first industrial R&D programs and stimulated the knowledge source roles of **universities and government** R&D institutions.
2	1993 ~ 1997	Stimulating participation of **industry** in national R&D programs to establish R&D networks among U-I-G.
3	1998 ~ 2002	Korean Government started the first industrial R&D programs for **SMEs and venture certification act** to stimulating R&D activities of SMEs and venture firms.
4	2003 ~ 2007	Stimulating R&D networks among U-I-G for advancing quantitative R&D outputs, such as scientific articles and patents.
5	2008 ~ 2012	Conducting long-term and technology-oriented R&D programs using program director's technology roadmap for each industry sector.

Source : : KEIT (2007), Park and Leydesdorff (2010), Chung (2007), and other sources.

Analysis: Triple Helix Analysis with U-L-S-V-G interactions

- Industry becomes the key actors since 1991 thanks to the Korean government's efforts
  => Large enterprises and SMEs are the key actors during the 2nd policy period (1993–1997) as a result of the policies for stimulating industry's participation
- Venture firms and SMEs are the key actors because the venture promoting policies are implemented in 1998(third policy period) and advance of IT creates new business chances

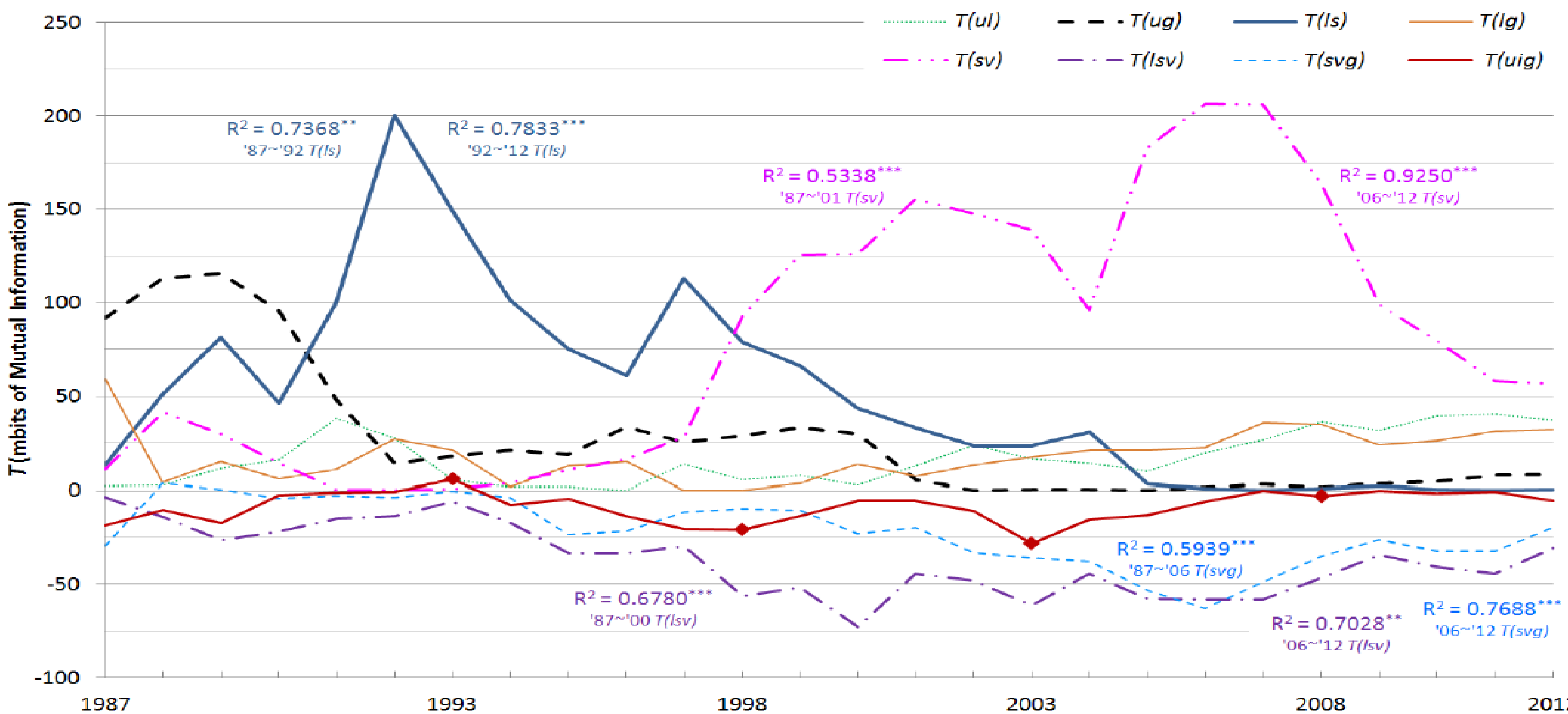


Figure. 4. Distinctive mutual information of the interactions among 5 actors

Problems

- The government policies for improving the synergy (i.e. SMEs and venture certification act) are only temporarily successful in the 3rd and 4th policies' beginning years (in 1998 & 2003)
  and even the policies' temporary effects steadily disappear year after year

- Interestingly, the most dynamic synergy occurs in 2003 when "SMEs and venture boom" collapses

- Synergy become lethargic since 2007 even if the 4th and 5th policies emphasize the importance of the synergy various institutional actors' participations, because each institutional actor conducts the R&D project alone and dynamic bi-lateral interactions disappear

VI. Implication

- Prior literature hints that the government should *"encourage, not control"* the interactions among Triple Helix institutional actors

- Korean government somewhat exceeds its encouraging role and conducts strict **direct policies** (which regulates the specific types of institutional actors in R&D networks), resulting in loss of synergy

  - Korea government's regulation might improve quantitative R&D outputs such as the scientific articles and patents given that institutional actors only need to accomplish planned R&D outputs without considering synergy or co-operation

  - The regulation mitigates the interactions among institutional actors because of the aggravated boundary or regulation of each institutional actor, caused by the strict direct policy, interferes with the dynamic interactions among the actors

VII. Concluding remarks

The policy makers should consider carefully the **unintended effects** of the policies before executing the policies

- Korean government's new direct policy for SMEs and venture firms brings in unexpected negative influence on synergy as well

- Thus, before the new direct policies are implemented, the policy makers should confirm that universities(U), industries(I), and government R&D institutions(G) continue to perform their own proper co-operative functions such as knowledge creation(U), products or processes innovation(I), and technology transfer(G) in a R&D network under the new policy

VII. Concluding remarks

The policy makers should check and reflect **feedback** from Tripe Helix institutional actors carefully because the feedback may operate positively or negatively

- Korean government's direct policies for improving the synergy are only momentary successful in the 3rd and 4th policies' beginning years and fail to continue to generate the synergy after the beginning years

This may be caused by the lack of periodical analysis on the feedback from the Triple Helix interactions

VII. Concluding remarks

The government should encourage, not force, the voluntary R&D networks using **Indirect policies** in Triple Helix model.

- Government should provide a meeting place or opportunity for flexible interaction among UIG actors.

  Flexible interactions with others by themselves using “networking/coordination support” are beneficial as they provide access to novel information and they offer linkages to divergent regimes of the networks

- Korean government should utilize Korean R&D big data system in order to find out possible collaborators and share information and knowledge among agents for new co-operation opportunities

Thank You