The Korea Institute for Industrial Economics and Trade (KIET) conducted a survey on technological or innovative structure of Korea manufacturing industries. More specifically, the study was derived from indices constituting input and output of research and development (R&D) through KIET Industrial Statistics Database (www.kietisdb.re.kr) consisting of 5,200 manufacturing firms. KIET concretely examined the input side of the R&D system through research and development (R&D) investment and numbers of researchers, level of R&D network among relating companies, collection of technological

Technological Input & Output Structure of Korean Manufacturing Industries in 2002

information, and the level of cooperation with foreign companies. Then the output structure of technology level compared with world technological frontier and Chinese manufacturing industries, effects of such technological efforts on sales, exports, and quality, etc, are analyzed. In this process, KIET examines the fusion phenomenon between existing technology and new technology including information technology (IT), biology technology (BT), nanotechnology (NT), environmental technology (ET), material technology (MT), and electronic technology.

1. The Overall Status of R&D in the Korean Manufacturing Industry

Eighty-five percent of Korean manufacturing firms are analyzed to be engaged in R&D, of which 84% presently possess in-house R&D organization.

The overall technology level of Korean manufacturing industries is found to be 'comparable, though still behind, with the world top level', showing an average of 80%. According to firms' responses, 30% of companies felt that the their level of technology's potential is very positive in terms of reaching the standard at ‘81～90% compared with the world’s best’, and 25% of companies responding that it will likely ‘catch up with the world level up to the 91～99% percentile’, in addition to 12% replying that their companies have ‘already reached the world’s best’.

As for industries, the technology level of IT industries is relatively high (84%), showing the best prospects of reaching the world’s top level. It is followed by the heavy and chemical industry and the light industry with an 80% level of world technological frontier, respectively. By firm size, large companies are found to possess a relatively higher level of technology (82%) than small and medium-sized companies (79%).

Furthermore, the Korean level of technology is found to be 5 years ahead, on average, than that of the Chinese manufacturing level, although the latter has been sharply making strides to keep pace as of late. Most companies (31%) respond with a ‘5 to 6-year level of higher advancement’, followed by 28% of companies stating ‘3 to 4-year higher advancement’. In contrast to these firms, 6% of companies responded as having the ‘the same level’ as the Chinese, and 1% of companies express that Korea’s level to be ‘falling short of the Chinese’. By industries, it is found that Korea’s level is more advanced than that of the Chinese in the heavy and chemical industry, while the gap between the two countries is trivial in the light industry.

Based on technological characteristics, the most underdeveloped technology of the Korean manufacturing industries relative to the best is pointed out to be the material-relating technology with the highest figure of 33%, followed by product design technology at 29%, and components and material processing technology at 12%. However, the assembly and processing technology is found to be relatively superior to the world standing at 7.3% percentile.

Eighty-five percent of all R&D is developmental research, which is producing new products with acquired knowledge from basic and applied research, or actual experiences, or research which can improve existing products or processes in 1～2 years. Applied research is research based on specific practical aims using the results or knowledge of basic research within 2～5 years, where 13% of the respondents are engaged in. And basic research, namely theoretical research for new science and acquiring knowledge without specific aims for application within 5～10 years, is considered to be unreliable occupied only 2% of all of R&D.

For R&D, product technology is found to be overwhelmingly greater (88%) than processing technology (12%). Concretely, the majority of responding firms is engaged in the development of new technology (51%), followed by the improvement of existing products (37%), while improvement of existing processes (9%) and development of new processes (4%) carry relatively low weight.

R&D investment in sales is found to record an average of 5.2%. Most companies (29% of the respondents) exhibit 1～2% R&D investment in sales, followed by 23% of companies showing 3～4%. 12% of companies replied that their R&D investment in sales is greater than 10%.

Based on industries, the IT industry belonged to the highest level (7%), followed by the heavy and chemical industry (5.1%), and the light industry (3.6%). According to company size, there was 4.8% small and medium-sized companies, and surprisingly are more significant than large companies at 3.4%.

The amount of R&D invested by korean firms is not at all insignificant in achieving a comparable level with the concurrent development of changing technology, but is still estimated by most companies to be lacking in the future development of new technology. Thirty five percent of companies felt that their current volume of R&D investment is enough to 'catch up with the development of changing technology', while thirty percent state 'inadequacy'. Companies that considered their potential to develop new technology as inadequate (37%) outweighed companies expressing an adequate level (28%).

In regards to investment sources for R&D, supply from reserve funds within the firm was discovered to be the majority (69%), followed by the dependence on the government's support of science and technology (19%), while there is no cooperation among companies engaged in the same sector of industries.

Furthermore, human resources in R&D of the Korean manufacturing industry is found to be an average of 8.8% of total employees. Concretely, 49% of companies responded with 1～5% of human resources in R&D as occupying the largest weight, followed by 23% of companies with 6～10%. According to industries, the IT industry is at the top with 14%, followed by the heavy and chemical industry (9%), and then, the light industry showing the smallest weight (5%). By firm size, small and medium-sized companies recorded more human resources of total employees (8%) than that of large companies (6%). Most firms felt an insufficient level of human resources in R&D was being addressed with to a comparable level with the current changes in technology or for developing new technology for the future. 45% of companies replied with 'not enough', outweighing the 22% of companies responding with 'enough'. Also, for the development of new technology, more companies (65%) replied with 'not enough' than companies responding with 'enough' (13%).

The method of R&D usually taken by Korean manufacturing companies is 'self and endogenous R&D', illustrating 57% weight, followed by joint R&D with 24%, the transfer of technology from foreign firms at 10%, and strategic R&D cooperation with 9%. It was found that domestic universities and research institutes are generally asked to be partners for joint R&D or strategic cooperation, recording 46%. Recently, a peculiar phenomenon in the area of R&D is that 64% of responding companies intend to entrust their R&D to R&D-specialized organizations when dealing with developing new technologies and fusion technologies, if they, for example of contract research organizations, are activated.

50% of domestic manufacturing companies responded that they have experienced difficulty in acquiring technology information relating to products and processes. As the source of technology information, they are utilizing demand companies very highly (30%), and then foreign companies (20%), other companies engaged in the same sector (16%), and research institutes & universities (14%) were also mentioned.

For the current on-going trends of combining existing technology with new technology, 43% of companies answered 'advocacy' to the combination. The main fields to promote the combination are 'MT' (19%), IT and ET (17%, respectively), electronic technology (15%), and BT (12%).

Overall, such technology efforts have resulted in a 'good', graded according to the 7-lykert scale (0:very poor, 4:average, 7:very good'). In particular, the effects of quality improvements (5.2%) are made at a very high level, and followed by the effects of sales expansion (4.8%), and the effects of exports expansion (4.5%).

The primary difficulty in placing newly developed products into the market were claims to discount prices by demand companies (39%). It is followed by similar products of other companies (24%), and dumping of imported goods (13%).

Moreover, it is shown that 32% of domestic manufacturing companies have been promoting R&D cooperation with foreign R&D institutes, responding to severe competition surrounding international R&D. The achievement of R&D cooperation with foreign institutes is evaluated to be above average with 4.5 on the 7 lykert-scale. In the process of international R&D cooperation, developmental research (78%) is found to be overwhelmingly greater than basic or applied research.

Regarding science and technology policies, Korean manufacturing companies preferring to expand their R&D funds was the highest response of 46%, which is followed by R&D cooperation among industry-university (research organizations) government with 14%, support of cultivating human resources on R&D at 13%, and improvements of R&D infrastructure with 12%. In contrast to these policies, it was realized that the direction of government's science and technology policies is shifting towards the support for S/W infrastructure from that of H/W infrastructure including expansion of advanced R&D facilities.

2. R&D Structure by Main Industries

Sectoral systems of R&D are analyzed by 10 main industries including automobile and components, electricity and electronics, semi-conductors, machinery and equipment, shipbuilding and other transportation, steel and metal, electrical machines, precision equipment, fiber, clothing, footwear, and chemistry.

It is found that technological levels of electronics (85%), semiconductors (83%), chemistry (81%), electrical machinery (82%), precision equipment (81%), and fiber and clothing (81%) are relatively positioned at a high level, compared with the world technology frontier, while the technological levels of automobiles (75%) and machinery (79%) are relatively low.

The technological gaps with China are shown to be, on average, 4～5 years advanced. But the differences in technological gap by industries are analyzed to be trivial, that is, 4～5 years advanced in all industries.

Based on the scope of technology, the underdevelopment of design technology causes a bottleneck to the progress of some industries including electronics, automobiles, and machinery, while most other industries point out the lack of material technology.

The amount of companies engaging in R&D activity is an average of 85%, showing high levels in electronics (93%) and chemistry (91%), while low levels in steel and metal (72%), fiber, clothing, and footwear (respectively, 81%).

Looking at the characteristics of R&D, developmental research is overwhelmingly high, with just below 80% in all industries, while applied research and basic research are comparatively low. Based on the contents of R&D in all types of industries, product technology is overwhelmingly more than processing technology.

In addition, the weight of R&D investments to sales amount is 5.2%, shown relatively high in electronics (8%), semiconductors (6%), and precision equipment (6%), while exhibiting the lowest results in steel, metal, fiber, clothing, footwear, and automobiles (respectively, 4%). The volume of such R&D investments is sufficient for gaining ground in the development of currently technological change in most industries, however it is estimated to be insufficient for the future development of new technology. More than 50% of R&D investments are supplied from reserve funds within companies in all types of industries.

The weight of human resources for R&D of total employees is an average of

8.8%, shown relatively high in electronics (16%), and semiconductors (12%), while being very low in fiber, clothing, and footwear (respectively, 5%), and steel and metal (6%). The level of human resources for R&D is assumed to be at an inadequate level and not quite up to par with the standard of developing current technological change and to enhance research capability of future new technology.

As for the method of R&D, self and endogenous R&D strategy occupies more than 50% in all types of industries, while showing low joint R&D and strategic cooperation. In particular, it is reflected that there is a high percentage of self and endogenous R&D in the electronics (75%) and semiconductor industries (69%). Domestic universities and research institutes are regarded as main institutions that are involved in joint R&D and strategic cooperation in all types of industries.

By industries, the fusion of main existing technologies with so-called new technologies including IT, BT, NT is promoted by 12～60% of manufacturing firms. In particular, the level of fusion is relatively high in semiconductors (61%), electronics (58%), and precision equipment (55%), while it is reflected to be low in automobiles (26%), and steel and metal (32%). The electronics, machinery, and electrical machinery industries are most obviously place importance on IT, while the automobiles, and steel and metal industries emphasize MT, with shipbuilding, and fiber and clothing industries on ET, with semiconductors on NT, with chemistry industry on BT, and with the precision equipment industry on electronic technology, as the main area of fusion technology.

Efforts towards R&D result in favorable improvements in all industries, First of all, the effects of sales expansion are shown as quite high between 4.6～5.2 on 7-scale lykert scale in all industries. By industries, high effects of sales expansion are shown in the semiconductor (5.2), electronics (5.1), precision equipment (5.0), and electrical machinery (4.9) industries, while relatively low effects are shown in fiber, clothing, and footwear industries (respectively, 4.6). Consequently, the effects of export expansion are estimated to be a little high overall with 4.2～5.1, shown by relatively good achievements in the semiconductor (5.1), shipbuilding (4.7), precision equipment (4.9), electrical

Table 1. Main Results on R&D by Korean Manufacturing Industries

		Total	Electrical	Semi-conductor	Automobile	Shipbuilding	Machinery and equipment
Level of technology to world top technology (%)		80	84.8	83.2	75.4	79.8	78.6
Difference in technology from China		4.7	4.2	4.4	4.8	5.4	5.0
Poor technology		Materials technology	Design technology	Materials technology	Design technology	Design technology	Design technology
Percentage of technology development execution		85	93.4	88.9	80.2	84.8	86.0
Development research/Total R&D percentage		85	86.9	90.3	87.9	88.0	88.7
Basic research/Total R & D percentage		2	1.2	3.2	4.6	0.0	1.1
R&D investment/Percentage of sales amount		5	7.8	6.2	3.7	4.2	4.4
R&D human resources/ Percentage of employees		8.3	16.2	11.5	6.1	6.0	7.2
Self-development/Total R&D percentage		57	75.3	68.8	44.8	52.0	54.7
Percentage of promotion of new technology combination		43	57.8	61.3	25.8	49.0	49.5
New technology area regarded as most important		Materials technology	Information technology	Nano-technology	Materials technology	Environ-mental technology	Information technology
Effects of technology development	Sales effect	4.8	5.1	5.2	4.7	4.8	4.7
	Export effect	4.5	4.6	5.1	4.3	4.7	4.2
	Quality improvement	5.2	5.3	5.3	5.1	5.3	5.2
Percentage of quality management		55	47.5	62.1	72.2	78.0	40.9
Achievement of quality management		4.3	4.5	4.6	4.4	4.5	4.4
Percentage of foreign cooperation		32	28.1	48.4	34.4	36.0	31.7
Achievement of foreign cooperation		4.5	4.9	4.3	4.6	4.6	4.8

		Steel&metal	Chemistry	Electronics, machinery	Precision equipment	Fiber& clothing
Level of technology to world top technology (%)		79.9	81.1	81.6	81.0	81.4
Difference in technology from China		5.0	5.0	4.5	4.0	4.4
Poor technology		Materials technology	Materials technology	Materials technology	Materials technology	Materials technology
Percentage of technology development execution		72.3	91.3	87.3	93.3	80.7
Development research/Total R&D percentage		82.5	77.9	89.6	84.1	84.1
Basic research/Total R & D percentage		0.0	2.2	2.1	1.5	6.3
R&D investment/Percentage of sales amount		3.6	5.2	5.6	6.3	3.8
R&D human resources/Percentage of employees		5.7	9.2	9.3	11.2	4.9
Self-development/Total R&D percentage		55.0	54.4	62.5	62.9	56.7
Percentage of promotion of new technology combination		32.2	51.9	40.9	55.1	35.9
New technology area regarded as most important		Materials technology	Bio technology	Information technology	Electronics technology	Environment technology
Effects of technology development	Sales effect	4.8	4.8	4.9	5.0	4.6
	Export effect	4.4	4.4	4.6	4.9	4.4
	Quality improvement	5.2	5.3	5.1	5.3	4.8
Percentage of quality management		54.7	57.6	77.8	58.2	30.2
Achievement of quality management		4.5	4.5	4.4	4.3	4.4
Percentage of foreign cooperation		28.6	40.6	28.9	35.8	13.1
Achievement of foreign cooperation		4.0	4.7	4.3	4.3	4.6

machinery (4.6), and electronics (4.6) industries, with low estimations in fiber and clothing (4.4) and machinery (4.2). The effects of quality improvements are found to be relatively optimal in technological results, with 5.0 acquired in all types of industries except for fiber, clothing, and footwear with 4.8.

The weight of companies promoting cooperation with foreign R&D institutions is found to be, on average, 13～48%, showing relatively low interest in the fiber, clothing, footwear (respectively, 13%), electronics (28%), steel and metal (29%), and electrical machinery (29%) industries, while exhibiting greater efforts in the chemistry (41%), shipbuilding (36%), precision equipment (36%), and automobile (34%) industries. The expansion of R&D funds is regarded as the most important aspect for all the industries as well as playing the most important role in terms of government R&D-support activities.

3. Regional Status of R&D in the Manufacturing Industries

Here, we analyzed the regional system of R&D.

Seoul Metropolitan City (Seoul) recorded the highest (85%) relative technology level among all local governments, compared with the world technological frontier, which is followed by the Chungcheongnam-do Province (Chungnam) with 84%, and Daejeon Metropolitan City (Daejeon) with 83%. In contrast to these provinces, Gwangju Metropolitan City (Gwangju) (72%), Chungcheongbuk-do Province (Chungbuk) (76%), Busan Metropolitan City (Busan) (76%), Gyeongsangbuk-do Province (Gyeongbuk) (77%), Ulsan Metropolitan City (Ulsan) (77%), and Gyeongsangnam-do Province (Gyeongnam) (78%) are found to register a relatively low numbers. Regional level of technology is realized to be advanced, averaging 4～5 years advancement to that of Chinese technology.

By technologies, most provinces regard material-oriented technology as the most underdeveloped technology. Companies engaged in material technology and industries in Incheon Metropolitan City (Incheon), Gangwon-do Province (Gangwon), and Ulsan point out that design technology is vital for improvement.

In regard to R&D activity, companies in Seoul recorded the highest (96%), followed by Daejeon and Incheon (respectively, 91%), and Gyeonggi-do Province (Gyeonggi) (90%), which are relatively higher compared with the nationwide average of 85%. In contrast to these provinces, Gwangju (67%), Jeollanam-do Province (Jeonnam)(70%), Ulsan (74%), Gyeongnam (76%), Gangwon (77%), Daegu Metropolitan City (Daegu) (79%), Jeollabuk-do Province (Jeonbuk) (80%), Busan (81%), and Chungbuk (83%) are found to be relatively lower than other provinces.

Concerning the characteristics of R&D, developmental research had an overwhelming occupancy in every area, with applied research at less than

10%, and basic research less than 5%. In particular, basic research is found to be at an inferior infrastructure in Gangwon, Jeonnam, Ulsan, and Gyeongnam.

In terms of weights of R&D investment towards sales amount, Daejeon had the highest record with 7%, followed by Seoul and Gyeonggi with 6%, respectively, which are relatively higher than the national average of 5%. Conversely, Daegu, Gyeongnam, Jeonnam, and Gyeongbuk recorded 4%, showing relatively lower weights.

The percentages of human resources for R&D of the total employees exemplified huge differences among provinces. By provinces, Daejeon occupied the highest record (15%), followed by Seoul (12%), and Gyeonggi (11%), which are higher than the national average of 8.8%. In contrast to these provinces, Jeonnam (4%), Gangwon, and Ulsan (respectively 5%) are found to be relatively low.

When speaking in terms of method of R&D, self and endogenous development is utilized by half, or more than half in almost all areas, but joint R&D recorded the highest (43%), especially in the Chungnam area. This seems to be making the best of the integration of research institutions in this area. It should be noted that the majority of outside research institutions or universities are the partners for joint R&D in most areas. Ulsan mentions companies engaging in the same sector as the partner of R&D, while the Gwangju and Jeonnam areas have partnerships with foreign institutions.

Based on this survey, more than 50% of the companies that replied in every region will likely promote the combination of existing technology with new technology including IT, BT, and NT. By provinces, Seoul makes recorded the highest (65%), followed by Daejeon (54%), and Jeonnam (50%), which are relatively higher than the national average. In contrast to these areas, Gwangju (25%) and Gyeongnam are found to have recorded relatively low levels.

With respect to new technology, Gyeonggi, Chungnam, Jeonnam, Gyeongnam, Gyeongbuk, and Ulsan regard MT as the most important technology. Seoul, Incheon, Daejeon, Gwangju, and Busan mention IT, with Gangwon, Chungbuk, and Daegu cite ET as vital, and Geonbuk expresses BT as crucial.

Table 2. Main Results on R&D by Korean Provinces

	Technology level	Percentage of technology development execution	R&D investment percentage	R&D human resource percentage	Percentage of promotion of new technology combination	New technology area regarded as most important	Effect of technology development		
							Sales effect	Export effect	Quality improve–ment
Total	80	85	5	8.3	43	Materials technology	4.8	4.5	5.2
Seoul	84.9	96.2	6.2	12.2	64.9	Information technology	5.0	4.6	5.3
Gyeonggi	81.7	90	5.9	10.9	47	Materials technology	4.9	4.7	5.2
Incheon	78.6	90.7	4.7	7.7	43.9	Information, electronics technology	4.9	4.5	5.1
Gangwon	82.9	77	4.5	4.7	42	Environmental technology	4.6	4.1	4.9
Daejeon	83.1	91.1	6.7	14.5	54.1	Information technology	5.1	4.8	5.4
Chungbuk	75.8	82.6	5.0	7.3	35.3	Environmental technology	4.7	4.2	5.1
Chungnam	83.8	88.2	5.0	7.8	40.0	Materials technology	5.0	4.7	5.1
Jeonbuk	79.4	80.4	4.5	6.6	34.3	Bio technology	4.8	4.4	4.9
Jeonnam	81.3	69.7	4.1	4.1	50.0	Materials, environmental, and bio	4.5	4.3	5.2
Gwangju	72.1	66.7	5.3	5.9	25.0	Information, environmental technology	4.6	4.2	5.1
Daegu	80.3	78.8	4.0	6.9	36.7	Environmental technology	4.8	4.7	5.4
Gyeongbuk	77.0	83.5	4.2	6.1	37.5	Materials technology	4.8	4.2	5.2
Busan	76.3	80.9	4.8	7.0	30.9	Information, environmental technology	4.2	3.8	4.9
Ulsan	77.4	74	4.4	4.9	41	Materials technology	4.3	4.3	5
Gyeongnam	77.9	76.2	4.0	6.7	27.1	Materials technology	4.6	4.3	5.0

Evaluated by the achievements of R&D efforts based on the 7-lykert scale, the effect of sales expansion was made by relatively higher than the national average of 4.8 in Daejeon (5.1), Seoul (5.0), Chungnam (5.0), Gyeonggi (4.9), and Incheon (4.9), while it was relatively low in Busan (4.2), Ulsan (4.3), Jeonnam (4.5), Gwangju (4.6), Gyeongnam (4.6), and Gangwon (4.6). In addition, for the effects of export expansion, Daejeon (4.8), Gyeonggi, Chungnam, Gwangju (respectively 4.7%), and Seoul (4.6) recorded higher than the national average, while Busan (3.8), Gangwon (4.1), Chungbuk (4.2), Gwangju (4.2), Gyeongbuk (4.2), Jeonnam (4.3), Ulsan (4.3), Gyeongnam (4.3), and Jeonbuk (4.4) recorded relatively low results. Finally, the effects of quality improvement, are relatively higher in Daejeon and Daegu (respectively 5.4) than other provinces, while Gangwon, Jeonbuk, and Busan (respectively 4.9) recorded relatively low numbers.

R&D cooperation with foreign research institutes exhibited significant differences among provinces. Ulsan (50%), Seoul and Chungnam (respectively 41%), Gyeonggi and Daejeon (respectively 35%) are relatively active, while Jeonnam (10%), and Jeonbuk (20%) are relatively low.

Among government's science and technology policies, the expansion of research funds is regarded as the most crucial means for all provinces. The improvement of the R&D infrastructure including industry-university (research institute) government cooperation for R&D, cultivation of human resources, and the globalization of standards (respectively, less than 10%) also bear some significance. In contrast to these policies, the expansion of high technology-embodied facilities and support for cooperation with foreign R&D institutes are understood as less important.

4. Summary and Policy Implications

First, the technological levels of the Korean manufacturing industry have the potential to be equal with the world's best, as well as being five years ahead of the Chinese. However, technological possibilities are focused only on developmental research for practical use within 2 years. Judging from the cycle of technological life, these gaps may be shortened, as long as the speed of catching up to the technologies of developing countries is quite rapid. To accomplish this, there must be an urgency to move towards the direction of R&D to upgrade or enhance technology based on the technology life cycle, which will be one of the original and applied technologies.

Second, though fusion of existing technology with new technology is taking place, there must be the need to emphasize demand-oriented science and technology policies, rather than present supply-pulled policies.

Third, self and endogenous R&D is presently preferred to technology transfer from foreign R&D institutes as a means to R&D by Korean manufacturing industries. This is due to the fact that domestic firms have been enjoying the achievements of developmental research made until now. However, there is the need to promote joint R&D and strategic cooperation with domestic and/or foreign R&D institutes. Such policies are crucial, when the possibility of currently competitive technologies can be achieved by developing countries, the demand for fusion technology, and the difficulties in developing new technologies are considered. More especially, technological cooperation with foreign firms should be promoted.

Fourth, as the government' s science and technology policy, the expansion of R&D funds, promotion of cooperation among industries, universities (research institutes), and government, and cultivation of human resources for R&D are more desired than the support of advanced technology-embodied equipments. This can be interpreted as the policies on science and technology should be changed from the support of hardware to the support of software. In particular, in response to the lack of R&D cooperation with foreign R&D institutes, the globalization strategies of R&D are very crucial, including joint global R&D.

Lastly, there is the need to completely consider the strong and weak points of regional innovation systems. In particular, it is considered optimal to incorporate a clustering technology or an industry combined with the specialized industries of each region.

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