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In Search of *Élan Vital* for Japan: Aging and Directed Technological Change: — Designing Optimum Gerontechnology as a Growth Engine —

Abstract

Japan has long struggled for change in the directions of the rapid aging of its population and the deplorable declining of its birth rate in the doldrums of deflationary pressures. To date, unfortunately, every policy measure has not yielded any successful outcomes. The attention of social security experts is now riveted exclusively to how to tinker the long-term care insurance (LTCI) system. What is missing in the current policy debate is the recognition that the well-being of the elderly will be deteriorated significantly even if the LTCI is completely fixed. Therefore, Japan is now expected to seek a challenge-driven innovative growth path which will concurrently effectuate solutions for population aging and low fertility as well as its burgeoning fiscal deficit. This short essay tries to shed light on the aging problem by highlighting a novel perspective based on directed technological change (DTC) models.[2] The DTC models provide a possibility of restructuring an economy through innovative technologies that would bring about substantial social security cost reduction. In order to reap the maximum benefits of the DTC, however, a broader institutional design should be laid out. The essay tries to gain a comprehensive picture in which (1) the silver market's size effect, (2) selective R&D support to encourage new entrants, and (3) building global networks will play a critical role in innovation in elderly care activities.

1. Introduction: Population Aging: A Worldwide Phenomenon

1.1 Aging at an Accelerated Pace

Nowadays, population aging is observed in nearly all the countries of the world. In particular, Japan's rapidly aging population is staggering. According to the Japanese government, the country's aged persons (those who are aged 65 or over) account for 25.8% of the total population as of March 2014.[3]

Table 1 Aging in Major Countries (Population Aged 65 or Over as a Percentage of the Total Population)

	World	Japan	China	Hong Kong	South Korea	S.E. Asia	Singa-pore	Thai-land	Den-mark	Swe-den	U.K.	France	Germa-ny	Nether-lands	United States	Canada	Austra-lia
2015	8.2	26.4	9.5	15.0	13.0	6.0	11.2	10.4	18.6	20.0	18.1	18.7	21.4	18.1	14.7	16.0	15.0
2020	9.3	28.6	11.7	18.2	15.5	7.1	13.9	13.0	19.8	20.7	18.9	20.3	23.1	20.1	16.6	18.0	16.4
2025	10.3	29.6	13.5	22.4	19.4	8.6	17.3	16.1	20.9	21.3	20.0	21.7	25.1	22.3	18.6	20.4	17.8
2030	11.6	30.7	16.2	26.5	23.4	10.3	20.5	19.5	22.1	22.0	21.7	23.2	28.2	24.6	20.2	22.7	19.2
2035	12.8	32.2	19.5	29.6	27.1	11.9	23.0	22.9	23.1	22.8	23.3	24.5	31.0	26.6	20.9	23.7	20.1

Source: United Nations, "World Population Prospects, The 2012 Revision, Medium Fertility."

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[2] As for the DTC models, see, for example, Daron Acemoglu, *Introduction to Modern Economic Growth*, Princeton, NJ: Princeton University Press; see also Daron Acemoglu, "Directed Technical Change," *Review of Economic Studies*, Vol. 69, No. 4 (October, 2002), pp. 781-810.

[3] See, the website: http://www.stat.go.jp/data/jinsui/new.htm.

Table 1 shows that the population aged 65 or over as the percentage of the total population in major countries, estimated by the United Nations. Table 1 also tells that by the year of 2035, several Asian countries including Japan, Hong Kong, and South Korea will be among the most silver-haired societies along with such European countries as Germany and the Netherlands. Among developed countries, the United States and Australia will be among the youngest in 2035. Aging is transforming itself with a growing number of "the oldest-old," i.e., octogenarians, nonagenarians, centenarians, and supercentenarians; the percentage of the oldest-old out of the total world population will reach 2.8% in 2035 from 1.7% in 2015 (see Table 2). This trend is expected to continue at an accelerated pace. In 2013, there are 120 million people who are 80 years old or older in the world. The figure for those who are octogenarian or older on the globe will be expected to grow precipitously, and reach 140 million and 392 million, in 2025 and 2050 respectively.[4] As Table 2 shows Japan's population aging is stunning; the percentage of those aged 80 years or over out of its total population will exceed 10% in 10 years. As for population aging, Japan will be followed by Germany and Hong Kong, while the United States will remain to be a country filled with younger people.

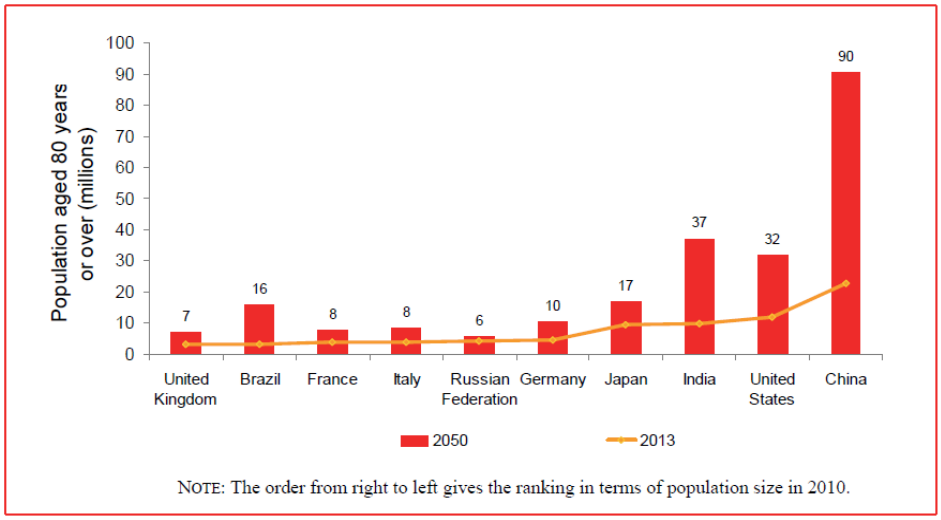
Table 2 The Oldest-old in Major Countries (Population Aged 80 or Over as a Percentage of the Total Population)

	World	Japan	China	Hong Kong	South Korea	S.E. Asia	Singa-pore	Thai-land	Den-mark	Swe-den	U.K.	France	Germa-ny	Nether-lands	United States	Canada	Austra-lia
2015	1.7	7.9	1.7	4.3	2.8	1.1	2.3	2.1	4.3	5.2	4.9	5.9	5.8	4.4	3.7	4.2	3.9
2020	1.9	9.3	1.8	4.9	3.7	1.2	2.8	2.6	4.7	5.4	5.2	6.1	7.3	4.8	3.9	4.4	4.2
2025	2.0	10.9	2.0	5.2	4.5	1.3	3.3	3.1	5.6	6.3	5.6	6.1	8.1	5.5	4.3	5.0	4.7
2030	2.3	13.0	2.5	6.5	5.5	1.5	4.6	3.8	6.7	7.5	6.6	7.5	8.1	7.1	5.3	6.1	5.7
2035	2.8	14.0	3.6	8.6	6.9	2.0	6.3	5.1	7.1	7.8	7.1	8.6	9.1	8.1	6.3	7.3	6.5

Source: United Nations, "World Population Prospects, The 2012 Revision, Medium Fertility."

Although the percentage of old people will remain relatively low, the size of the aged population in China is enormous. Figure 1 shows that the number of the population who are octogenarian or older in major countries. As of 2013, China has 23 million old persons who are 80 years old or over and the estimated figure for 2050 looks frightening—90 millions of octogenarians or over.

Figure 1 Top Ten Countries with the Largest Population Agued 80 Years or Over in 2013



Source: United Nations, "World Population Ageing 2013", New York: United Nations, 2014, p. 33.

[4] United Nations, "World Population Ageing 2013," New York: United Nations, 2014, p. 32.

Now, the next largest country having the oldest-old is the United States with 12 million persons. Then, India and Japan follow China and the United States with 10 million and 9 million aged people respectively.

1.2 Difficulties Facing Aged People

Undeniably aging has pervasive influence on both collective and individual lifestyles. Individually, aged persons encounter difficulties originating from age-related frailty, disability, and diseases. According to a 2013 survey conducted by Japan's Ministry of Health, Labour and Welfare, 25.8% of persons aged 65 or over confess that they have difficulties because of aging or other reasons (see Tables 3 and 4). As Table 3 shows, the older the Japanese grow, the higher percentage, the age cohorts register. Out of the Japanese, 12.6% of them confess that they have physical or psychological difficulties. Out of the Japanese aged 75 or over, 35.3% of them encounter difficulties; the aged people of 85 years old or over, 47.8% of them complain about their difficulties.

Table 3 People Suffering Physical/Psychological Problems in Japan (Multiple Choice; Percentage of Each Age Cohort)

Total	Age Cohorts																		
	6 ~ 9	10 ~ 14	15 ~ 19	20 ~ 24	25 ~ 29	30 ~ 34	35 ~ 39	40 ~ 44	45 ~ 49	50 ~ 54	55 ~ 59	60 ~ 64	65 ~ 69	65 ~	70 ~ 74	75 ~ 79	75 ~	80 ~ 84	85 ~
12.6%	2.4	3.9	4.2	4.3	5.1	5.9	7.0	7.6	9.0	10.7	11.9	13.2	15.2	25.8	20.2	27.1	35.3	36.9	47.8

Source: Ministry of Health, Labour and Welfare, "Heisei 25-nen Kokumin Seikatsu Kiso Chosa [平成 25 年 国民生活基礎調査/Basic Survey of Japanese Life in 2013]," Table 79.

Table 4 informs us of detailed information about difficulties for elderly people in Japan. Among the Japanese aged 65 or over, 11.9% of them complain about their problems regarding daily living, 11.8% of them confess their frustration at the time of their outing; 9.4% of them, working, and 8.3% of them, exercise.

Table 4 Major Difficulties Facing Aged People in Japan (Multiple Choice; Percentage of Each Age Cohort)

	Difficulties (Total)	Daily Living	Outings	Working	Exercise	Others
Aged 65 or Over (Total)	25.8	11.9	11.8	9.4	8.3	3.4
Male	24.1	10.8	9.8	7.3	9.1	3.3
Female	27.1	12.9	13.4	11.1	7.7	3.4
Aged 75 or Over (Total)	35.3	18.5	18.4	12.7	10.1	4.2
Male	32.7	16.3	15.8	9.6	11.1	4.2
Female	37.1	20.0	20.2	14.8	9.4	4.2
Aged 85 or Over (Total)	47.8	30.7	27.7	15.7	12.0	5.3
Male	43.9	26.5	25.4	12.6	13.4	5.0
Female	49.6	32.7	28.9	17.2	11.3	5.4

Source: Ministry of Health, Labour and Welfare, "Heisei 25-nen Kokumin Seikatsu Kiso Chosa [平成 25 年 国民生活基礎調査/Basic Survey of Japanese Life in 2013]," Table 79.

With regard to the Japanese aged 75 or over, 35.3% of them complain about their difficulties in their lives. Among them, 16.3% of older men confess their difficulties associated with daily living, while 20.0% of older women bemoan their problems concerning daily living. Such differences between men and women can be presumably ascribed to differences in the average age within the age cohort. Since women live longer in general, within the same age cohort, the average age of older women is higher than that of older men. Therefore, aging problems within the same age cohort are more serious in the case of older women than that of older men (In 2013, the sex ratio is that 75.3 men to 100 women as for older people aged 65 or over).

1.3 Difficulties Facing Aged Societies

In addition to difficulties facing elderly individuals, aging societies also encounter various difficulties in terms of socio-economic terms. In 2010, more than half of Japan's population was older than 45 years, and there has been a growing dark cloud hanging over the sustainability of the social security system in the middle of a creeping depopulation (see Table 5). At the same time, with rapid population aging, the institutional framework and organizational structure are being forced to reformulate in order to build better workplace security and safety procedures suitable for older workers.

Amidst continued public spending pressures and its declining population, Japan should secure financial and human resources for growing needs for elderly care. In other words, Japan should develop goods and services for elderly care with cost-effectiveness and higher productivity. At the same time, a combination of depopulation and population aging is forcing Japan to effectuate novel solutions for the elderly care workforce by developing equipment to reduce the burden of caregivers that are also growing older, or alternatively by increasing the number of caregivers through the introduction of the foreign worker systems. In sum, Japan is pressed to face squarely a challenge-driven innovation to diffuse pressures on economic and human resources.

Table 5 Japan's Creeping Depopulation amidst Rapid Aging (Millions of Persons)

Age Cohort ↓	1955	1970	1985	2000	2010	2015e	2020e	2030e	2040e	2050e	2060e
Total	89.3	104.7	121.1	126.9	128.1	126.6	124.1	116.6	107.3	97.1	86.7
0〜14	29.8	25.2	26.0	18.5	16.8	15.8	14.6	12.0	10.7	9.4	7.9
15〜59	52.2	68.4	77.1	78.5	71.0	68.3	66.1	59.5	50.1	43.9	38.5
60〜64	2.5	3.7	10.0	10.0	10.0	8.5	7.3	8.2	7.8	6.1	5.7
65〜69	2.0	3.0	5.4	7.7	8.2	9.7	8.2	7.4	8.9	6.6	5.6
70〜74	1.4	2.2	4.2	5.9	7.0	7.8	9.2	6.7	7.6	7.2	5.7
75~	1.4	2.2	3.6	9.0	14.1	16.5	18.8	22.8	22.2	23.8	23.4
Population Aging Rate	5.3	7.9	10.3	17.4	23.0	26.8	29.1	31.6	36.1	38.8	39.9
Old Age Dependency Rate	11.4	9.8	6.6	3.9	2.8	2.3	2.0	1.8	1.5	1.3	1.3

Note: Figures for the years 2015 and after are estimates.
Source: Ministry of Health, Labour and Welfare.

1.4 Gerontechnology: A Promising Solution?

The term gerontechnology is a "composite word combining gerontology and technology which means the study of technology and aging for the improvement of the daily functioning of the elderly."[5] Gerontechnology has a combination of various disciplines with the single purpose of serving aging society. Therefore, it includes such related science and technologies as life science, sensor technology, micro and nanotechnology, material technologies, and information and communication technology (ICT) to name a few (see column (4) in Table 6).

As mentioned above, older people experience age-related frailty, disability, and diseases. Here, before discussing the future of Japan's gerontechnology, we will examine the relationships among (1) age-related frailty as various and different sources of demand, (2) challenges of aging as a list of prospective goods and services for older people, (3) activity areas as conditions for the prospective goods and services are consumed, and (4)

[5] As for the definition of gerontechnology, see, for example, Ryoko Fukuda, "Gerontechnology for a Super-Aged Society," in *The Silver Market Phenomenon: Marketing and Innovation in the Aging Society*, second edition, edited by Florian Kohlbacher and Cornelius Herstatt, Heidelberg: Springer, 2011.

required gerontechnology as source for developing such goods and services.

Table 6 Aging Issues: Frailty, Challenges, Activity Areas, and Required Technologies

(1) Frailty associated with Aging	(2) Challenges of Aging	(3) Activity Areas	(4) Required Gerontechnology
Mental Ability	Health and Wellness	Food and Nutrition	Life Science
Sensory Capability	Independence	Clothing	Sensor Technology
Cognitive Capability	Mobility	Shelter	Micro and Nanotechnology
Physical Conditions	Security and Safety	Health and Medicine	Material Sciences
Technological Competencies	Social Participation	Education and Leisure	ICT
Values and Beliefs		Transportation	

Source: The authors.

(1) Frailty Associated with Aging

Generally speaking, the older people become, the more slowly they adopt new lifestyles and technologies; sometimes older people regard new lifestyles and technologies as "enemies" of their own.[6] This weakened mental ability leads to the lessening of intellectual curiosity to accept new technologies despite a clear understanding of the usefulness of the technologies. At the same time, older people experience declining capabilities regarding sensory organs, cognitive functions, and physical strength. Coupled with the weakened mental ability, those limited capabilities tend to lead to incompetence to utilize gerontechnology, and rejectionism and technophobia. For this reason, in order to develop user-friendly gerontechnological equipment, product designers and engineers as well as sales managers should create carefully an environment and methods in order to reduce older people's psychological and physical barriers against the adoption of new technologies.

(2) Challenge of Aging: Physiological Aging

Many experts enumerate age-associated diseases and the characteristics of those diseases.[7] The characteristics of physiological aging are as follows: (a) most elderly person have several different and/or chronic diseases simultaneously,[8] (b) huge differences in conditions and biophylaxis functions among individuals,[9] (c) huge differences in disease symptoms and efficacy of medicines between younger people and the elderly,[10] and so on.

Accordingly, it is dangerous to oversimplify the argument of challenges of aging. However, when Japan is to develop novel gerontechnology, some sort of typology can contribute to a clearer understanding of the challenges facing elders. Broadly speaking, gerontechnological goods and services are classified in the following way—(a) health and wellness, e.g., food and nutrition, exercises, and geriatric nutrition, (b) independence, e.g., equipment to promote self-care among the independent elderly, (c) mobility, e.g., mobility equipment devices for the elderly, (d) security and safety, e.g., monitoring and preventing systems handling the wondering of senile dementia, and (d) social participation, e.g., programs and equipment to promote senior socialization.

6 See, for example, Hans-Werner Wahl and Heidrun Mollenkopf, "Impact of Everyday Technology in the Home Environment on Other Adults' Quality of Life," in *Impact of Technology on Successful Aging*, edited by Neil Charness and K Warner Schaie, New York: Springer, 2003.

7 See, for example, Japan Geriatrics Society (日本老年医学会), "Koreisha ni taisuru Tekisetsu na Iryo-teikyo no Shishin [「高齢者に対する適切な医療提供の指針」/Guidelines for the Provision of Appropriate Medical Services toward Elderly Persons]," March 2013.

8 See, for example, Council of the Royal College of General Practitioners, "Compendium of Evidence," February 2013.

9 See, for example, David J. Lowsky *et al*., "Heterogeneity in Healthy Aging," *Journals of Gerontology: A Biological Sciences and Medical Sciences*, online November 2013.

10 See, for example, Harinder Chahal, "Comparative Safety and Efficacy of Glibenclamide in the Elderly: Should Elderly Patients with Type 2 Diabetes Be Treated with Glibenclamide (glyburide) or Different Sulfonylurea?" Geneva: World Health Organization (WHO), 2012.

(3) Activity Areas

The aforementioned arguments have to be cross-examined by each activity area when it comes to develop prospective goods and services. Various researchers classify goods and services in the elderly care and related industries. Table 7 shows representative goods and services that are expected to be developed for the future. In a later section, we will come back to these subjects in detail.

Table 7 Elderly Care: Its Activity Areas and Related Demands

Customers →	Patients	Healthy People	Older People	The Public at Large
Activity Areas ↓	Medical Industry	Health Promotion	Elderly Care	Others
Food and Nutrition	Diet for Patients	Healthy Diet Guideline	Geriatric Diet	Food Safety
Clothing	Clothing for Hospitals	Sports Clothing	Senior Clothing	
Shelter	Heath Architecture	Healthy Building Systems	Fully Accessible Houses	Energy-efficient Houses
Health and Medicine	Medical Equipment	Health-care Equipment	Medical Equipment, Telemedicine	Regional Heath Care System
Education and Leisure	In-hospital Excises	Exercise Services	Elderly Exercises	Solutions to Digital Divide
Transportation	Emergency Medical Transport	Leisure Vehicles	Senior Transportation Services	
Others		Home Use Equipment		Insurance

Source: The authors.

(4) Required Gerontechnology

As mentioned above, gerontechnology is a collective set of amalgam of various technologies, ranging from life science and sensor technology to micro and nanotechnology and material technology. Of course, in addition to these sciences and technologies, ICT and managerial sciences have been incorporated into gerontechnology.[11] At the same time, fiscal constraints have forced those who are engaged in providing services for elderly care to pay attention to various activities that would be more cost effective.[12] In a concluding section, we will come back to this issue again.

2. Directed Technological Change (DTC)

2.1 Theoretical Implications of DTC in the Pharmaceutical Industry

As an authoritative DTC advocates, Daron Acemoglu argues that "Models of directed technological change not only generate new insights about the nature of endogenous technological progress, but also enable us to ask and answer new questions about recent and historical technological developments."[13]

DTC has been developed since the early years of the 21st century. In 2003, two MIT economists named Daron Acemoglu and Joshua Linn published a theoretical and empirical analysis of the U.S. pharmaceutical industry with a special emphasis of identifying the effects of market size for different types of drugs on entry of new drugs and innovation.[14]

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[11] See, for example, Soledad Ballesteros *et al.*, "An ICT-mediated Social Network in Support of Successful Ageing," *Gerontechnology*, Vol. 13, No. 1 (2014), pp. 39-48; See also Alexandra König *et al.*, "Use of ICT for the Assessment of Dementia Patients," *Gerontechnology*, Vol. 13, No. 2 (2014), pp. 81-82.

[12] See, for example, Juan J. Baztán et al. "Effectiveness of Acute Geriatric Units on Functional Decline, Living at Home, and Case Fatality among Older Patients Admitted to Hospital for Acute Medical Disorders: Meta-analysis," *BMJ* (older name: *British Medical Journal*) No. 338 (January 2009); See also Ayumi Kono *et al*., "Effects of Preventive Home Visits on Health Care Costs for Ambulatory Frail Elders: A Randomized Controlled Trial," *Aging Clinical Experimental Research*, Vol. 25 No. 5 (August 2013), pp. 575–581.

[13] Acemoglu (2009), *op. cit*., p. 497.

[14] Daron Acemoglu and Joshua Linn, "Market Size in Innovation: Theory and Evidence from the Pharmaceutical Industry," NBER Working Paper, No. 10038, 2003; See also Daron Acemoglu and Joshua Linn, "Market Size in Innovation: Theory and Evidence from the Pharmaceutical Industry," *The Quarterly Journal of Economics*, Vol. 119 No. 3 (2004), pp. 1049-1090.

The economists identify the magnitude of the response of entry of new drugs and pharmaceutical innovation to changes in potential market size of users, driven by U.S. (or OECD) demographic changes. They conclude that an iota of 1% increase in the potential market size for a drug category "leads to approximately 4-to-6% growth in the entry of new drugs approved by the FDA."[15] They also look to competition policy and conclude that "This response comes from the entry of both generics and non-generics, though the effect on generics is larger and somewhat more robust." Additionally, given the facts that there are smaller markets in the developing world and that there are a large number of intractable diseases (*nanbyo*/難病 in Japanese) with a smaller number of patients, the economists suggest that international collaboration for medical innovation regarding these intractable diseases and should take into consideration of the significance of this market size effect.[16]

Based on this seminal work, Acemoglu continues to examine the relations among market size, factor endowments, and national policies. For example, Acemoglu and Linn tried to evaluate the policy effectiveness of Medicare by asking if Medicare increases drug spending by the elderly, and if the pharmaceutical companies would have to respond to the change in market size for drugs caused by Medicare.[17] Acemoglu and his colleagues at Harvard University and the University of Chicago conclude that "evidence does not provide support for the hypothesis that Medicare had a major effect on the direction of pharmaceutical innovation."[18]

In the meantime, Acemoglu applies the DTC models to the nagging environmental problems in his 2009 paper entitled "The Environment and Directed Technical Change," and conclude that (i) sustainable long-run growth can be achieved with temporary taxation of the fossil energy-related innovation and production; (ii) optimal policy involves both "carbon taxes" and R&D subsidies; (iii) delay in intervention is costly: the sooner and the stronger is the policy response, the shorter is the slow growth transition phase; (iv) it is optimal to redirect technical change towards clean technologies immediately and optimal environmental regulation need not reduce long-run growth. He also suggests that environmental regulation adopted only in the developed world may be sufficient to avoid a global disaster.[19]

2.2 Aging and DTC: A Theoretical Consideration

The authors have been enthusiastic to develop countermeasures against the rapid aging of its population and the deplorable declining of its birth rate with the help of DTC models. Currently, the attention of social security experts is riveted to how to tinker the long-term care insurance (LTCI) system, when there are faced with the draconian fiscal constraint. What is missing in the current policy debate, however, is the recognition that the well-being of the elderly will be deteriorated significantly even if the LTCI is completely fixed. Therefore, Japan is now expected to seek a challenge-driven innovative growth path which will concurrently effectuate solutions for population aging and low fertility as well as its burgeoning fiscal deficit.

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15 Acemoglu and Linn (2003), *op. cit*., p. 34.

16 See, for example, Michael Kremer, "Pharmaceuticals and the Developing World," *Journal of Economic Perspectives*, Vol. 16, No. 4 (2002), pp. 67-90.

17 Daron Acemoglu *et al*. "Did Medicare Induce Pharmaceutical Innovation?" NBER Working Paper No. 11949, January 2006.

18 *Ibid*.

19 Daron Acemoglu *et al*., "The Environment and Directed Technical Change," NBER Working Paper No. 15451, October 2009.

The DTC models help develop an alternative scheme in which the growing number of the elderly causes change in market structure and factor endowment, with which a substantial impact will be produced on medical and pharmaceutical innovation, leading to cost reduction of the social security system that is now expected to overwhelm threateningly Japan's aging society.

As briefly discussed in the previous section, the rapid aging of its population is exogenously set and hard to change its direction in the short run. According to the DTC models, this exogenous trend will change the direction of innovation of an economy.[20] Without challenge-driven innovation explained by the DTC models, conventional wisdom offers a gloomy prospect that Japan's aging society is economically encumbered and the elderly are confined to segregated communities with a fewer number of caregivers. As mentioned in the previous section, Japan's population aging rate exceeds 25% in 2014. Given a stable rate of old age dependency between 1.5 and 2.5 for the next 2 decades, machinery and equipment for elderly care services are expected to be relatively abundant compared with a shrinking young population.

Without innovation in gerontechnology that was discussed briefly in the previous section, the elderly care services industry will remain to be labor-intensive, and there will be an acute shortage of labor supply for elderly care services, leading to a rampant wage hike in the elderly care services industry. Higher labor costs will in turn bring about a narrower window of opportunity for the provision of high-quality hand-operated care services and substantial lessening in the quality of life (QOL) for the elderly even when the social security provision is kept unchanged. Thus a growing number of the oldest-old, the elderly care facilities and caregivers cannot maintain the qualitative and quantitative levels of elderly care services. In sum, hand-operated care services are expected to be substituted to machine-operated and automated services, or at least to a combination of hand-operated and equipment-supported elderly care services.

Under such circumstances, the DTC models predict that organizations, both for-profit and non-for-profit, will try to reduce the use of resources that are relatively expensive including physically strong and young or experienced caregivers. The models also foretell that elderly care organizations will seek capital-intensive technology to maintain or increase the quantitative and qualitative levels of elderly care services.

This drastic shift in the elderly care services industry from labor-intensive to capital-intensive brings about various benefits for the Japan's aging society. First of all, capital deepening of the industry will enhance productivity and reduce fiscal pressures facing Japan's social security system. Second, this shift enhances the accessibility of unskilled and aged caregivers who are now hindered or hesitant to enter the labor market of the elderly care services industry because of the severity of labor conditions.[21] To date, the severity of labor condition in the industry has been well known in Japan—as 3K, i.e., "*kitanai*, *kiken*, *kitsui*/汚い, 危険, きつ

[20] This discussion is also developed among other economists. See, for example, Bernardo S. Blum, "Endowments, Output, and the Bias of Directed Innovation," *Review of Economic Studies*, Vol. 77, No. 2 (2010) pp. 534-559.

[21] As for the difficulty of securing workers in the industry in Japan, see, for example, Shinya Sugawara and Jiro Nakamura, "Can Formal Elderly Care Stimulate Female Labor Supply? The Japanese Experience," Working Paper CIRJE-F-924, Center for International Research on the Japanese Economy, University of Tokyo, March 2014.

ㄟㄟ," or Dirty, Dangerous and Demeaning, known as 3Ds in the United States.

This shift from labor-intensive to capital-intensive in the elderly care services industry provides several possibilities of spillovers. First, machine and equipment which support caregivers will provide a wider possibility of the use of these machine and equipment for elder people who receive in-house care services with the help of their family members. Currently, those family members hesitate to take care of their parents and/or grandparents at home because of the severity of the working condition and time constraints. With gerontechnological products, family members, irrespective of being male or female, or, young or old, can provide elderly care less laboriously to care recipients who are the members of their families or communities. Second, older adults who want independence can utilize gerontechnological goods and services to maintain their self-care attitude. For example, with walking assistant equipment, ambulatory elders can enjoy a boarder spectrum of activity, enhancing their QOL and reducing the risk of contracting diseases.

2.3 DTC: Alternative Policy for Avoiding Looming Bankruptcy of the Social Security System?

In his seminal work, Acemoglu looked to the importance of competition policy; the industry's innovative response to a growing market is strong, and such response is larger and more robust when the entry of new competitors is encouraged. Accordingly, the government, when it tries to accelerate the pace of innovation in the elderly care services industry, should pay attention to designing a competitive market scheme in the industry.

At the same time, the special characteristics of the elderly care services market should be taken into account, i.e., information asymmetry, leading to a market failure, if appropriate institutional design is not laid out. Care recipients and caregivers are often thought to have little knowledge about gerontechnological goods and services, medicine, and government supporting systems. Accordingly, such asymmetry of information between the demand side, i.e., the elderly people, and the supply side, i.e., the care services providing organizations, might place the former in a disadvantaged position.[22]

Table 8 shows the number of older people who are recognized by the Ministry of Health, Labour and Welfare that they are eligible to receive public support regarding nursing care or support within the framework of long-term care insurance (LTCI) or "*kaigo hoken*/介護保険."

Currently, more than 5 million elder people are admitted to receive public assistance. But these care recipients complain about the lack of information as well as staff and facility deficiencies.[23] Given the continuously increasing number of elder people who need nursing care, the issue of information asymmetry should be examined and corrected in the future. Information asymmetry, which favors innovative companies in the industry by being blessed with lucrative businesses, can run concurrently the risk of escalating the social

[22] As for problems associated with asymmetry of information in the industry, see, for example, Pierre L. Yong and Leigh Anne Olsen, *The Healthcare Imperative: Lowering Costs and Improving Outcomes*, Washington, DC: The National Academies Press, 2010, and Jae-Young Lim, "The Effect of Patient's Asymmetric Information Problem on Elderly Use of Medical Care," *Applied Economics*, Vol. 39, No. 16 (2007), pp. 2133-2142.

[23] The authors notice that at the local government level, there are various types of complaints about lack of information and explanations raised by elder people.

security costs. For this reason, some researchers suggest "Transparency—of the costs, prices, quality, and effectiveness of medical services and products—has been identified as a key tool to lower costs and improve outcomes." [24] Therefore, ITC-aided monitoring system should be concurrently developed when such challenge-driven innovation system is constructed.

Table 8 Number of Older People Requiring Nursing Care (Millions of Persons)

			2006	2007	2008	2009	2010	2011	2012
Total number			4.25	4.38	4.52	4.70	4.91	5.15	5.46
Require Nursing Care	Most Serious	Level V	0.47	0.48	0.49	0.54	0.57	0.59	0.59
	Very Serious	Level IV	0.53	0.56	0.57	0.61	0.62	0.65	0.67
	Serious	Level III	0.62	0.68	0.71	0.69	0.68	0.70	0.72
		Level II	0.72	0.77	0.79	0.82	0.86	0.91	0.96
		Level I	0.87	0.75	0.76	0.83	0.88	0.94	1.02
Require Support	Serious	Level II	0.49	0.61	0.64	0.63	0.65	0.69	0.74
		Level I	0.52	0.54	0.56	0.59	0.65	0.68	0.75

Note: Figures are for those who are eligible to receive public-funded care or support based on the 1997 Law Concerning Insurance for Nursing Care (介護保険法) (revised in 2005, 2008, and 2012). As Table shows there are 7 levels at which elder adults receive care in terms of different economic and non-economic terms.
Source: Ministry of Health, Labour and Welfare.

2.4 DTC Is Not Enough—Designing A Comprehensive Policy Framework Coupled with the DTC Models

According to the DTC models that confirm the substantial magnitude of market size effect, Japan's industry producing medical devices and care robotics are expected to enjoy such effect because Japan is ranked extremely high in terms of both the percentage of the aged people and the size of aged population (see Table 9). Table 9 shows Japan is ranked 1st in terms of the percentage of the people aged 60 or over and 4th in terms of the size of the aged population.

However, this industry still remains in their inception phase. The frontier for medical devices are being expanded by U.S. and European companies, and major industrial agglomeration lies in Sweden and Denmark where in which the size of population aged 60 or over is extremely small (2.4 million and 1.3 million respectively).

Table 9 Population Aging and Market Size Effect 2013

Ranking by Percentage of Population Aged 60 or Over (%)			Ranking by the Size of Population Aged 60 or Over (Million)		
1	**Japan**	**32.0**	1	China	187.3
2	Italy	26.9	2	India	102.7
3	Germany	26.8	3	United States	70.5
4	Bulgaria	26.1	**4**	**Japan**	**40.7**
5	Finland	26.1	5	Russian Federation	27.0
6	Greece	25.4	6	Brazil	22.0
7	Sweden	25.2	7	Germany	21.6
8	Croatia	24.8	8	Indonesia	19.7
9	Portugal	24.5	9	Italy	16.1
10	Latvia	24.1	10	France	15.7
11	Estonia	23.9	11	United Kingdom	14.7
12	Denmark	23.8	12	Pakistan	11.5
13	France	23.8	13	Mexico	11.4
14	Belgium	23.8	14	Spain	10.7
15	Hungary	23.7	15	Bangladesh	10.6

Source: United Nations.

[24] Yong and Olsen, *op. cit*.

Without doubt, another consideration including the size of elderly care cost or social security cost should be examined. Nonetheless Table 9 suggests that Japan's restructuring of the social security system requires additional policy rearrangements in order to reap the maximum benefit of the market size effect through the DTC models. In order explore further analysis, in the next section, an industry-wise, or meso-level analysis will be briefly presented.

3. Aging and DTC: Meso-level Analyses

3.1 Gerontechnological Innovation: Applicable Areas Revisited

As mentioned in the beginning of this essay, gerontechnology is a comprehensive body of technology which serves to achieve a better quality of life (QOL) for the elderly. Accordingly, there has been and will be a novel set of ideas and technologies to replace older ones. Here, among gerontechnological goods and services, innovation in the fields of medical devices and assistive robotics is discussed.

(1) Innovation in the Medical Device Industry

One of the most observable particularities in the medical device industries is the sheer number of products which is a reflection of a wide variety of diseases and associated medical treatments, especially in the fields of care services of older adults with multimorbidity.

Table 10 shows the long-term statistics of Japan's medical device industry. The number of medical devices introduced in a year has grown by about 40% since the early 1990s, while production has increased by about 30%. Generally speaking, Japan's medical device industry has not grasped completely a widening window of opportunity compared with their foreign competitors. For this reason, while Japan's export amount of medical devices has increased by 50% since the early 1990s, the import figure for these devices has also risen sharply over 130% during the same year. In other words, Japan's medical device industry has received opportunities and benefits to a lesser extent emerging from Japan's rapid aging. At the same time, foreign competitors have acquired adroitly business opportunities and experiences for businesses overseas in Japan.

Table 10 Japan's Medical Equipment Industry: Long-term Statistics (1000 items; Trillions of Yen)

	1992	1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011
No. of Items	107	108	109	111	116	114	112	115	117	117	119	124	132	128	134	136	126	147	148	157
Production	1.37	1.34	1.32	1.34	1.46	1.51	1.52	1.49	1.49	1.52	1.50	1.50	1.53	1.57	1.69	1.68	1.69	1.58	1.71	1.81
Exports	0.33	0.30	0.29	0.27	0.30	0.33	0.33	0.37	0.36	0.40	0.38	0.42	0.43	0.47	0.53	0.58	0.56	0.48	0.45	0.48
Imports	0.39	0.46	0.50	0.59	0.71	0.75	0.83	0.83	0.82	0.84	0.84	0.88	0.96	1.01	1.10	1.02	1.09	1.07	1.06	1.06
Stock (year end)	0.22	0.23	0.25	0.27	0.28	0.28	0.31	0.33	0.33	0.30	0.33	0.36	0.39	0.46	0.67	0.43	0.48	0.44	0.44	0.45

Source: Ministry of Health, Labour and Welfare, *Yakuji Kogyo Seisan Dotai Tokei Nenpo*, [薬事工業生産動態統計年報/Annual Report of Production Statistics in Drug Industries],

Under these dire circumstances, policy redirection is underway.[25] However, according to the *MD+DI* (Medical Device and Diagnostic Industry), one of the industry's professional media, 5 Japanese firms are included as global players.

[25] See, for example, the Ministry of Economy, Trade and Industry (METI), Healthcare Industries Division, Commerce and Information Policy Bureau, "Overseas Development of Japanese Medical Care—Toward a Medical Industry That Meets Global Demand—, September 2013.

Japan's leading medical device company is Terumo (ranked 19th in Table 11). The company is established in 1921, and produces artificial organs including hearts and lungs. It is also a leading supplier of hypodermic syringes and needles. The company is aggressively developing businesses in the global electrophysiology (EP) market, consisting of ablation catheters, diagnostic catheters and lab systems. The market growth has been achieved thanks to technological innovation and the Asia-Pacific region presents the most promising market. However, in this market, Terumo's competitors including Boston Scientific (ranked 13th), Johnson & Johnson (top), Medtronic (4th), and Abbot Laboratories (26th) are also demonstrating their competence in the region.

Olympus (ranked 21st) is the global leading maker of gastrointestinal endoscopy systems. Toshiba Medical Systems (ranked 23rd) produces diagnostic medical imaging systems. Hoya (ranked 34th) is, like Olympus, a global leading company producing medical endoscopes. Finally, Miraca Holdings (ranked 39th) is one of the global leading companies of in vitro medical test equipment. Other smaller companies in Japan have specific technologies but they have not yet benefited from this growing market brought about by Japan's aging society.

Table 11 Top 40 Medical Device Companies in the World

Rank	Company Name
1	Johnson & Johnson (U.S.)
2	Siemens AG (Germany)
3	General Electric Co. (U.S.)
4	Medtronic Inc. (U.S.)
5	Baxter International Inc. (U.S.)
6	Fresenius Medical Care AG & Co. KGAA (Germany)
7	Koninklijke Philips Electronics NV (Netherlands)
8	Covidien plc (Ireland)
9	Novartis AG (Switzerland)
10	Cardinal Health Inc. (U.S.)
11	Stryker Corp. (U.S.)
12	Becton, Dickinson and Co. (U.S.)
13	Boston Scientific Corp. (U.S.)
14	Essilor International SA (France)
15	Allergan Inc. (U.S.)
16	St. Jude Medical Inc. (U.S.)
17	3M Co. (U.S.)
18	Zimmer Holdings Inc. (U.S.)
19	**Terumo Corp. (Japan)**
20	Smith & Nephew plc (U.K.)
21	**Olympus Corp. (Japan)**
22	Getinge AB (Sweden)
23	**Toshiba Corp. (Japan)**
24	Bayer AG (Germany)
25	CareFusion Corp. (U.S.)
26	Abbott Laboratories (U.S.)
27	CR Bard Inc. (U.S.)
28	Dentsply International Inc. (U.S.)
29	Varian Medical Systems Inc. (U.S.)
30	Hologic Inc. (U.S.)
31	Intuitive Surgical Inc. (U.S.)
32	Paul Hartmann AG (Germany)
33	Drägerwerk AG & Co. KGaA (Germany)
34	**Hoya Corp. (Japan)**
35	Danaher Corp. (U.S.)
36	BioMérieux SA (France)
37	Coloplast A/S (Denmark)
38	Edwards Lifesciences (U.S.)
39	**Miraca Holdings Inc. (Japan)**
40	Sonova Holdings (Switzerland)

Source: *MD+DI*, December 14, 2013, (http://www.mddionline.com/article/top-40-medical-device-companies).

Relentless advancement in gerontechnology, growing complexity of medical treatment, and the industry's statistical deficiencies altogether negate any opportunities of detailed analyses, but we tentatively discuss a

future direction for Japan's medical device industry. Here, based on the classification of the industry, we analyzed the market size and competitiveness of Japanese firms (see Table 12).

After conducting various literature and hearing surveys, we tentatively, target fields in the industry, aided by the DTC models, are (1) measuring and monitoring systems for bio-phenomena (produced by firms including Olympus and Hoya) and (2) operating equipment and supplies (produced by firms including Terumo).

Table 12 Japan's Medical Device Industry: Market Size and Japan's Competitiveness

Classification	Market Size	Japanese Companies' Competitiveness
Image Diagnosis System	Big	Weak
X-ray Diagnostic Apparatus	Small	Weak
Measuring and Monitoring Systems for Bio-phenomena	**Big**	**Strong**
In Vitro Medical Test Equipment	Small	Weak
Operating Equipment and Supplies	**Big**	**Strong**
Clinical Equipment	Small	Strong
Artificial Internal Organ Apparatus and Assist Devices	Big	Medium
Therapeutic and Surgical Equipment	Big	Weak
Dental Equipment	Small	Strong
Dental Supplies	Small	Strong
Steel Products for Medical Use	Small	Strong
Ophthalmic Goods and Related Products	Big	Weak
Hygiene Products	Small	Strong
Therapy Apparatus for Home Use	Small	Strong

Source: The authors.

(2) Innovation in the Assistive Robotics Industry

(a) Central Government Policies: Selective Support Promising Robotics Areas

The Japanese government, under the Abe administration, accelerates its support for the development of assistive robots. For example, the Ministry of Economy, Trade and Industry (METI) and the Ministry of Health, Labour and Welfare have recently devised a series of robotic assistive technologies on a larger scale. In November 2012, the two Ministries announced "The Four Priority Areas where Robotic Technology Is to Be Introduced in Nursing Care of the Elderly (November 2012)." Currently, METI is now supporting 20 innovative companies to develop and sophisticate gerontechnological goods and services (see Table 13).

Table 13 Companies Which Receive Government Support for 2013

Product Classification	Name of Product	Company	Headquarters
Transfer assistive robots (wearable & non-wearable)	*HAL*	Cyberdyne	Ibaragi
	Muscle suit	Kikuchi Seisakusho	Tokyo
	non-wearable transfer assistive robot	Fuji Machine Mfg.	Aichi
	transfer aid equipment	Toyota	Aichi
	Robohelper Sasuke	Muscle, Inc.	Osaka
	RoboticBed	Panasonic	Osaka
	ankle walking assist device	Yasukawa Electric	Fukuoka
Mobility assistive robots	*Otasuke Walker*	Azbil	Tokyo
	electric wheelchair	Imasen	Gifu
	walking assist cart	Funai Electric	Osaka
	walking assist cart	Kawamura Cycle	Hyogo
Elderly hygiene assistive equipment	hygiene and nursing care product	Aronkasei	Tokyo
	hygiene and nursing care product	TOTO	Fukuoka
Surveillance systems	surveillance system for drug regular dose	Clarion	Saitama
	Watch Over Sensor	King Tsushin Kogyo	Tokyo
	non-contact tracking system for dementia patients	Ideaquest	Tokyo
	monitoring systems for the elderly, *Rakuchin-mimamori-Raku-mihma*	Super Regional	Tokyo
	monitoring platform using camera and smart rubber sensor	Tokai Rubber Industries	Aichi
	monitoring agent network robot for dementia patients	Pip	Osaka
	tracking system using three-dimensional electron mat	NK Works	Wakayama

Source: Ministry of Economy, Trade and Industry (METI).

(b) Local Government Policies: Reduction of Robophobia and the Digital Divide

Local governments have also been enthusiastic about the promotion and introduction of assistive robots. For example, in 1997, faced with rising concerns about population aging, the Kanagawa Prefectural Government established a non-for-profit organization "Kanagawa Fukushi Sahbisu Shinko-kai" whose activities cover the sophistication for the enhancement of efficiency and efficacy of a wide range of elderly care services.[26] In 2010, the organization started projects comprising (1) experimental introduction of assistive robots, (2) attitude surveys of caregivers and managers of the elderly care facility to examine the possibility of marketization of assistive robots, and (3) promotion activities of assistive robots.

As mentioned in the first section, some of aged care recipients, caregivers, and managers of caregiving services regard assistive robots as "enemy." Such "robot allergy" itself should not be simply criticized nor neglected. Accordingly, activities of experimental introductions, attitude surveys, and promotion play a critical role for the development of assistive robots by classifying users of assistive robots into (1) positive advocates, (2) rational adapters, (3) skeptic and ambivalent users, or (4) "robot allergic" rejectionists. As the Kanagawa Prefectural Government demonstrates an impressive example, Japanese local governments are expected to play a larger role in elder-specific and caregiver-specific ICT training to reduce robophobia and the digital divide.

Learning from the Kanagawa experience, Okayama City launched an assistive device leasing program in January 2014, the first project among local governments in Japan.[27] The municipal government provides 90% financial support to the users of three products (a) *PARO*, a baby harp seal-shaped neurological therapeutic robot being discussed below, (b) *Odayaka Taimu*, a detecting system for elderly wondering, and (c) *Power-Assist Glove*, a wearable robot to assist hand grasping in daily living of older or disabled persons.

(c) Self-help Activities Conducted by Research Organizations and Private Companies

In addition to the companies listed above, Japanese companies and engineers are conducting excellent research projects in this field. For example, social assistive *PARO*, a baby harp seal-shaped neurological therapeutic robot, is an oft-quoted case (The current manufacture of *PARO* is Intelligent System Co.). This world-famous *PARO* was chosen as a Best of Computer Dealers' Exhibition (COMDEX) finalist in 2003. The designer of *PARO*, Takanori Shibata, of the Intelligent System Research Institute of the National Institute of Advanced Industrial Science and Technology (AIST), explains the two reasons for its pervasive use since the development of the product in the late 1990s. First, it has substantial therapeutic effects on those from children to the elderly. Second, it has recognizable effects on elders, particularly those with some cognitive impairment. This year, the engineer reports the recent results of clinical experiments done on those mostly diagnosed with dementia.[28]

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[26] As for the detailed information, see the website of Kanagawa Fukushi Sahbisu Shinko-kai (only in Japanese), (http://www.kaigo-robot-kanafuku.jp/)

[27] As for the detailed information, see the website of Okayama City (only in Japanese), (http://www.city.okayama.jp/hofuku/hokenfukushiseisaku/hokenfukushiseisaku_00084.html). Nanto City in Toyama Prefecture also started the experimental introduction of PARO. See the website (https://www.city.nanto.toyama.jp/cms-sypher/www/service/detail.jsp?id=12391).

[28] Takanori Shibata and Joseph F. Coughlin, "Trends of Robot Therapy with Neurological Therapeutic Seal Robot PARO," *Journal of Robotics and Mechatronics*, Vo. 26, No. 4 (2014), pp. 418-419.

Honda Motor's *Asimo*, an advanced humanoid robot, also attracts the world's attention. Honda started its research in the humanoid field in 1986, and unveiled the two-legged *Asimo* for the first time in 2000. Now, Honda says "it envisions its robots performing dangerous tasks or assisting the elderly or bedridden."[29] Thus Honda raises a hope for the future of two-legged robotic maids and nurses for the elderly care.

3.2 Gerontechnological Innovation: Problems on the Horizon

(a) Is Japan the Leader of the Assistive Robotics Industry?

Contemplating the future of population aging, Japan is endowed with a favorable environment. First, the market size effect is potentially substantial as the DTC models suggest. Second, Japan has highly competitive companies, though few in number. Third, government policies correctly support the development of robotic assistive technology. Here, approaches to further accelerate this directed technological change in the gerontechnology are examined.

A 2012 document of the Organisation for Economic Co-operation and Development (OECD) entitled "The Robotics Innovation Challenge" raises a question about Japan's leadership: "Japan: Assistive Robotics Leader or Market Perception?"[30]

> "Anecdotal reports imply that the Japan leads the world in elder care robotics manufacturing. A recent story from Fox News in the US reported, 'If you grow old in Japan, expect to be served food by a robot, ride a voice-recognition wheelchair or even possibly hire a nurse in a robotic suit — all examples of cutting-edge technology to care for the country's rapidly graying population' (Fox News, 2007).[31] . . .
> Despite having developed technologically sophisticated prototypes, Japanese assistive robotics manufacturers have not gained any empirically measurable market lead over developers in the United States and the European Union."

The OECD report points out obstacles to Japan's market leadership in the global assistive robotics industry—(1) high prices, (2) limited demand, and (3) lack of standardization. However, these three obstacles are common difficulties facing assistive robotics manufacturers in other regions though the extent of difficulty might be varied. In the meantime, some researchers add another problem facing Japan—the galapagosization of the Japanese industry.[32]

(b) Beyond Galapagosization: Importance of Global Research and Business Networks

As mentioned in the previous section, Sweden is one of the most competitive countries in the assistive robotics industry. The country is ranked 7th in terms of the percentage of population aged 60 or over but the size of its aged population is less than 6% of that of Japan. Despite its disadvantage of the market size effect, Sweden has demonstrated its fast advancement in research and business development in this field. Here, the Swedish

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[29] Bloomberg, "Obama's Robot Pal Tapped by Honda for Driverless Car Edge," April 14, 2014, (http://www.bloomberg.com/news/2014-04-24/obama-s-robot-pal-tapped-by-honda-for-driverless-car-edge.html).

[30] Organisation for Economic Co-operation and Development (OECD), Directorate for Science, Technology and Industry (DSTI), "The Robotics Innovation Challenge," Paris: OECD, June 2012, pp. 28-29.

[31] Fox News, "Japanese Building Robots to Help Elderly," October 8, 2007, (http://www.foxnews.com/story/2007/10/08/japanese-building-robots-to-help-elderly/).

[32] See, for example, Fumikazu Kitagawa, "Growing beyond Galapagosization—A Strategy for Approaching Emerging Markets Utilizing Japanese Business Expertise—," NRI Paper No. 146, , Tokyo: Nomura Research Institute (NRI), September 2009, Peter Dyloco, "The Galapagos Syndrome and Japanese Cell Phones," November 8, 2010, (http://injapan.gaijinpot.com/live/tech/2010/11/08/the-galapagos-syndrome-and-japanese-cell-phones/),and William Pesek, *Japanization: What the World Can Learn from Japan's Lost Decades*, Singapore: Wiley, 2014.

experience, especially, the case of Robotdalen (in Swedish, meaning Robot Valley), is briefly discussed for the contemplation of Japan's future.

Robotdalen is a collaborative body which was established in 2003, comprising industry, academia and public organizations in the counties of Södermanland, Västmanland and Örebro in Sweden. Robotdalen is now regarded by some experts as the mecca of robotics research and commercialization.[33] According to the aforementioned OECD report evaluate Robotdalen by stating that "No other robotics innovation project offers a similar combination of research driven innovation joined with pragmatic strategic planning in order to build and scale new companies."[34]

An oft-quoted stylized case demonstrating this Robotdalen-initiated business success is Giraffe Technologies AB, a manufacturer of remotely controlled, mobile robots for the home environment. The Silicon Valley-born company commercializes mobile devices for care receivers and caregivers equipped with a camera and monitor providing remote assistance and security to the elderly in their own homes. In 2009, this rapidly expanding company moved their business from the United States to Sweden, and it became Robotdalen's first international business establishment.[35] In this way, Robotdalen actively expands and sophisticates its global networks. Recently it strengthens its tie with India. Currently, in a project named Seamless affordable assistive technology for health (SAATH), it tries cooperate with Swedish KTH Royal Institute of Technology in developing new innovative aids for the elderly, by incorporating sensors in shoe soles to check up on people's mobility and determine when it's time for a cane or a walker (a walker is specific walking equipment). The project's collaborative members include a number of Indian participants.[36]

Although several Japanese researchers and business persons know about Robotdalen, few of them keep abreast with the rapid developments within Robotdalen. In order to achieve leapfrog progress for elderly care, Japanese who are concerned with this area should develop and sophisticate comparable globalized networks. Through literature and interview surveys, the authors came to realized that much of information that is extremely resourceful in content lacks English translations. Without English translations, few people outside Japan cannot know the detailed information regarding the assistive robotics industry in Japan.

As for the future of Robotdalen, it would be very difficult to predict. To date, it has achieved successful results despite the lack of the potential market size effect of its own country. The OECD report evaluates the past record of Robotdalen by stating that "coordinated efforts between entrepreneurs, economic policy planners and business strategists can yield real results."[37] Indeed, Robotdalen has been enthusiastic to attract the attention of researchers and companies around the globe to compensate the paucity of market size effect.[38] However, the

[33] See the website of Robotdalen (http://www.robotdalen.se/?language=en&language=en).
[34] OECD (2012), *op. sit*., p. 32.
[35] See the website (http://www.robotdalen.se/en/about-robotdalen-robotdalen-swedish-robotics-cluster-new-robot-innovations?language=en).
[36] See the website (http://www.robotdalen.se/en/article/en-robotdalen-commercial-partner-india-project-kth).
[37] OECD (2012), *op. cit.*, p. 32.
[38] Here, although we judge that Sweden's market size effect is small, a different perspective suggests otherwise. Among OECD countries, Sweden's share of long-term elderly care costs as a percentage of GDP in 2008 was the highest (3.6%), while that of Japan was 1.6% according to

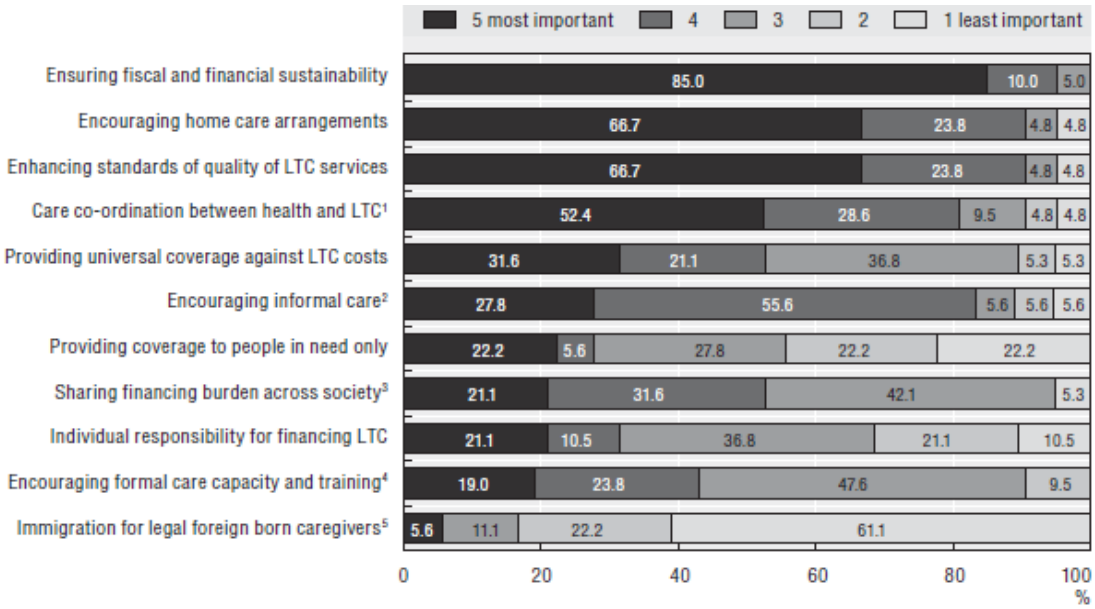
uncharted waters of population aging lie ahead of Robotdalen.

In the age of globalization, to meet the global challenges such as aging, climate change, terrorism, and pandemics, isolated and fully integrated research and business organization cannot achieve any fruitful results in terms of effectiveness, efficiency, and speed. Today's R&D has become more complex and multidimensional. In order to keep competitive and creative in any industry segment, innovative organizations must be smaller, less integrated, less complex, but networked to find the most appropriate collaborative partners irrespective of nationality or industry sector. This globally networked organizational model can flexibly and fully utilize external resources and opportunities.

Japan's assistive robotics industry, despite its excellent technological resources, has not yet reaped the maximum benefits of its silver market size effects. By taking full advantage of government support, the industry should expand and sophisticate its global research and business networks.

Without doubt, long-term elderly care is one of the world's front-burner issues and the time bomb of the snowballing social security cost is ticking (see Figure 2).

Figure 2 Pressing Issues for Long-term Care in OECD Countries



Source: Francesca Colombo *et al*., "Help Wanted? Providing and Paying for Long-term Care," Paris: OECD, 2011, p. 39.

However, to tackle squarely the fiscal and financial sustainability by tinkering the social security system is not necessarily a correct response. As this essay suggests, a different approach through technological innovation might be effective and efficient, and time-saving.

an OECD study (Francesca Colombo et al., "Help Wanted? Providing and Paying for Long-term Care," Paris: OECD, 2011, p.46).

4. Conclusion

Japan has long struggled for change in the directions of the rapid aging of its population and the deplorable declining of its birth rate in the doldrums of deflationary pressures. To date, unfortunately, every policy measure has not yielded any successful outcomes. The attention of social security experts is now riveted exclusively to how to tinker the long-term care insurance (LTCI) system. What is missing in the current policy debate is the recognition that the well-being of the elderly will be deteriorated significantly even if the LTCI is completely fixed.

Therefore, Japan is now expected to seek a challenge-driven innovative growth path which will concurrently effectuate solutions for population aging and low fertility as well as its burgeoning fiscal deficit. This short essay tries to shed light on the aging problem by highlighting a novel perspective based on DTC models. The DTC models provide a possibility of restructuring an economy through innovative technologies that would bring about substantial social security cost reduction. In order to reap the maximum benefit of the DTC, however, a broader institutional design should be laid out.

The essay has gained a hypothetical but comprehensive picture to approach the difficult issue of social security system in the middle of population aging and the burgeoning fiscal deficit. First, the silver market's size effect is substantial as Acemoglu suggests. At the same time, this size effect should be carefully coordinated with competition policy to encourage new entrants, and additional arrangements to reduce information asymmetry which might put aged care recipients and caregivers in an unfavorable position. But this huge size effect is not a necessarily sufficient condition as the current situation in Japan shows. Second, selective government supports are needed to accelerate innovation. Third, in the age of globalization, to build and sophisticate global research and business networks is extremely important especially regarding innovative and globally challenging agenda including the elderly care.