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Japan in the Edo Period: Global Implications of a Model of Sustainability

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Introduction

Humankind is truly at a crossroads. It may either degenerate into oblivion destroying its abode, the Earth, or it may change course and sustain its civilization for the foreseeable future. The material that is available to humankind and all our co-inhabitants of the Earth is physically limited, and the energy that is usable for long is only that from the Sun. All other energy sources are exhaustible, and will not last long at the current rate of exploitation. Materials naturally available (or at least readily usable) are usually present in a relatively low-entropy state. Once such materials are processed, utilized and discarded/dispersed into the environment, their entropy is enormously increased. Then it is hardly possible to recover it in a low-entropy state. Hence, though they never disappear, such materials are non-renewable in practice. This writer has attempted to estimate the resource availability of major elements on the Earth and the anthropogenic exploitation rate (Ochiai, 2004).

We, human beings, are only one of several million species of organisms on this Earth, and we have to share the resources available with other living organisms. Only we, as conscious beings, can change our way of life by our own volition. If we continue our (meaning "wealthy nations") present way of life, the overexploited planet will eventually retaliate, forcing change upon us.

Spaceship Earth as seen from Apollo 10

Human history has recorded numerous examples in which civilizations collapsed because of overexploitation of the environment (Ponting, 1993; Diamond, 2005). Such experiences were more or less local. However, what we are now facing is a possible collapse of the spaceship Earth itself, or rather the human civilization on it. This spaceship is closed in terms of material; i.e., no significant amount of material comes in and out. The only significant input is solar energy, the only truly renewable resource available to all living creatures on the Earth.

Therefore, an ultimately sustainable society should use only solar energy and other

(virtually) inexhaustible energy sources such as geothermal and tidal, while making judicious use of non-renewable resources. Wind power and hydropower also depend on solar energy.

The present world human population is about 6.2 billion and the terrestrial surface area is 1.49×10^8 km^2, which means that the population density is 42/km^2. The question is then how to construct a sustainable human civilization with this current population (or perhaps a more appropriate population, likely less than the current one), where the term "sustainable" is used in the sense of the previous paragraph.

Japan is a country consisting of four small islands, completely surrounded by sea. During the Edo period (1600-1867) it inadvertently experimented to sustain itself virtually without input of energy and material from the outside; i.e., depending solely on solar energy. The population density during the Edo period was approximately 80/km^2, which is a quarter of the current population density of Japan and about twice the present world population density. In a sense, it was a small-scale model for the spaceship Earth. It not only succeeded in sustaining the relatively high population density and a vibrant culture, but also improved its environment; that is, it increased its forested area, and made the soil more fertile and the waterways cleaner.

Japan was at the time an agrarian, pre-industrial society with a significant level of manufacturing. Industrialization starting in the mid 18th century in the West enormously changed the material and energy use of mankind. It is the major reason for increased material wealth of mankind in general, but it is also the major cause of the present crisis of environmental degradation and excessive resource exploitation. It may not be possible to go back to pre-industrial society, but mankind has to approach as closely as possible that level of resource use if it is to sustain itself. Hence the Japanese experience merits reflection.

The Edo Centuries

Japan had been a fairly open (to the outside world) society until about 1615. Free trade was conducted with a number of European countries, and with China and Korea. Material was transported in and out of Japan, though perhaps the total amount was not very significant compared to the GNP at the time. However, Japan was in a state of perpetual internal war during the 16th century, as many warlords fought for hegemony. This internal war devastated the Japanese lands, and reduced the population.

After Tokugawa Ieyasu won a crucial battle in 1600, the emperor gave him the title of Shogun (Generalissimo) in 1603. The Tokugawa clan established its Shogunate system based in Edo (today's Tokyo) and completed the unification of Japan in 1615. They tried to remove the Christian (Catholic) influence on some daimyo (warlords) and their regions, because they saw the Christian doctrine as a grave threat to the secular authority of the Shogun. Eventually they banished all Christian missionaries, and banned all foreign trade and communication except for that with China, Korea and the Netherlands (1637). The Dutch convinced the Shogun that Protestant Holland would not be a threat, and that they were not interested in spreading Christianity. Their coming and going was, however, strictly controlled and they were allowed only to reside on one small island off Nagasaki. The Japanese themselves were forbidden to travel abroad. Hence Japan virtually closed itself to the outside world, in terms of material, energy and human population, importing only a very limited amount of luxury items such as silk from China and books from the Netherlands, and exporting silver, gold and later ceramics.

In a sense, Japan embarked on a large-scale survival experiment, based on the material and energy available on the four islands and the

surrounding sea, which provided some food and other resources such as salt and also means of transportation. While living standards were far from low by Asian and even European standards at the time, many poor farmers barely subsisted, and some faced starvation when crop failures hit them, which happened often (Pomeranz, 2003; Chapter 12, Totman, 1993).

Nonetheless, many, including farmers, could participate in cultural activities, and hence their lives were far from subsistence level. The domestic culture was developed for the general public (as well as the powerful and the wealthy) in literature, performing arts, paintings, woodblock prints, and even mathematics. Tens of thousands of “sangaku” were produced.

Sangaku illustration

People of all walks of life including farmers participated in solving fairly complex mathematical problems, and the successful results were displayed on a plaque at temple or shrine; this was called “sangaku”, and people did it just for fun (Rothman, 1998; Sugimoto and Swain, 1989). It has been suggested that Japan in that period was the top among the nations of the world in the volume of books published, which presupposed the existence of a high level of popular literacy, as discussed below.

Not only did the Japanese collectively sustain themselves and their society, but they also improved (rather than degraded) their environment; i.e, they made their rivers and the surrounding sea cleaner and their soil more fertile, and they increased the forested area (Diamond, 2005).

Edo Political Economy

Once the Shogunal system was established, a peaceful condition persisted for the subsequent two and a half centuries. This was the single most important factor allowing Japan to sustain itself, for materials and energy did not have to be wasted, and the environment destroyed. In 1721 the government began to take a census every 6 years; hence there is a relatively reliable record of population thereafter. The population increased rapidly once peaceful conditions came to prevail during the 17th century, then it flattened out and remained more or less constant at about 30 million throughout this period, i.e., about one quarter of the current population of Japan. The constant population was not a result of governmental regulation, but of natural causes and intentional actions by people. Famines caused by crop failure s were a major reducing factor. It seems that people tried to lower the birth rate in general, and that some form of abortion and infanticide were practiced at times when increasing population pressure overwhelmed the food availability (Totman, 1993). It has been suggested that the Japanese system of inheritance may also have contributed to the stabilization of population, only first-born sons could inherit from their parents, and other siblings therefore faced heavy strictures not only on income and consumption but even the ability to marry and procreate.

The Japanese diet consisted of rice, vegetables and occasionally fish, but rarely meat, and the meat consumed was mainly obtained by hunting, such as bird and wild boar, not of domestically raised animals such as pigs and cows. Cows and horses were kept, but mostly for the purpose of transportation. This diet is much more energy efficient than one dependent on meat.

80 per cent of the population were farmers who

produced food for themselves and the rest of the population. The rest consisted of "Bushi" (samurai warriors) and townspeople, merchants and artisans. Bushi (about 6 per cent of the total population) was the ruling class and was not involved in economic activities or production processes. Under the Tokugawa system, their original role, that of warrior, lapsed, and high-level Bushi became bureaucrats. Because their salaries (given in terms of rice) were fixed and mostly inherited, they became relatively impoverished as time progressed. Low-level Bushi (i.e., on lower salary) suffered from economic hardship. They therefore turned to various ways to supplement their income: teaching, writing, some special jobs and even farming. Merchants on the other hand gained economic power and became the main movers of popular culture.

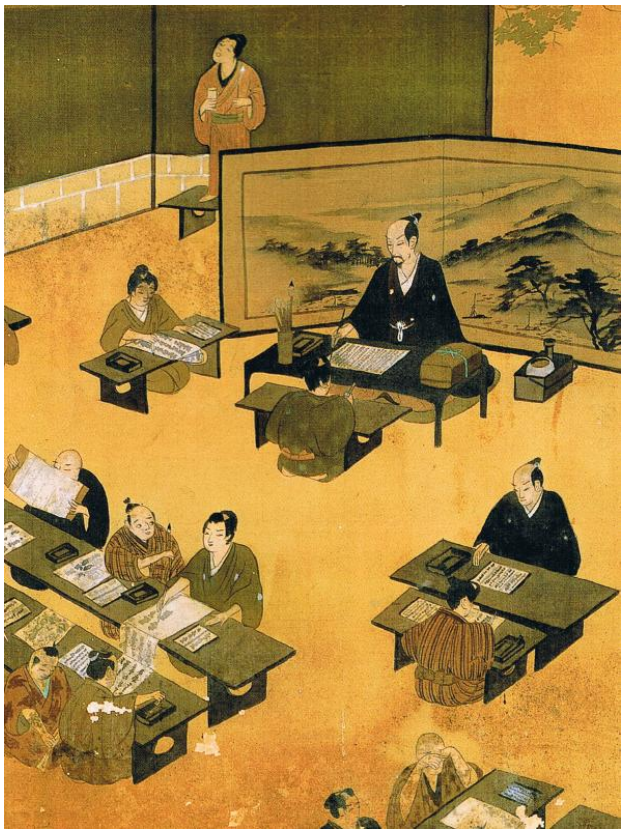
Firearms, first introduced by Portuguese in mid 16th century, were used extensively in the internal war period (up to 1615), but once peace prevailed, their use declined and their development was neglected. Bushi adopted the sword as their status symbol. Toward the end of the 16th century, i.e., before the Tokugawa rule started, by decree weapons were confiscated from everybody except for warriors ("Katanagari"). In the beginning of the Meiji era (1870's), swords were removed from the former Bushi (as depicted in the movie "Last Samurai"), and since that time it became a norm in Japan that nobody was allowed to carry weapons except for regular military personnel and a few special professionals (licensed hunters, *etc*).

City streets and highways were remarkably safe. The city of Edo had only 24 policemen, all ranks included, when its total population was believed to be about 1.2 million (quoted in Ishikawa, 1997b) [1]. The total number of bureaucrats for this megalopolis, including police, was about 280. This reduced the number of people to be fed, and eased social sustainability.

Japan was divided into about 260 autonomous regions (called "han"), each of which had an independent administration, with the Tokugawa being simply the largest and strongest "han". The Tokugawa government devised an elaborate system to keep other "han" in line (e.g. see Chapter 4, Totman, 1993), but the Tokugawa allowed each "han" to run its own business on its own term, unless it threatened the authority of the Tokugawa. It was a kind of federal system, where problems were addressed by the local people most affected by the changes to be made and also most familiar with the problem, though in many cases permission from the Tokugawa was necessary. However, the Tokugawa was also sufficiently strong in terms of political power so that it controlled every detail of the conduct of people, especially those of Bushi rank, and even influenced the development of technology, when such a development might jeopardize their authority. For example, wheeled carts were forbidden in Osaka, the second largest city, because their use was considered to be a threat to the livelihood of other transporters serving the authorities (Itasaka, 1987). Society was far from being free or ideal.

The Tokugawa established a national university in Edo, and each "han" followed suit, establishing han schools for the education of the Bushi. In addition, a large number of private institutions of various kinds including medicine, philosophy, mathematics and flower arrangement appeared, and they admitted people irrespective of social status. For example, one private medical school established by Ogata Koan admitted students from townspeople and farmer class as well as Bushi (Itasaka, 1987). Tera-koya (literally "temple-hut") served the general public, and were known by that name because such education was initially conducted by monks Later this became a general name for private basic educational institutions, which typically taught children of all ages basic skills: reading, writing, arithmetic and abacus (Ichikawa and

Ishiyama, 2006). The Tokugawa government imposed no regulation on these institutions. More than half of the population, and as much as three quarters of the children in big cities, received at least a basic education at these institutions, including, in many places, even poor farmers' sons and daughters.



Tera-koya

Edo Energy

Except for a very minor use of non-renewable fossil fuel (coal) in certain regions, all the energy used (including human power or labor, plants, water- and wind-mills) was provided by the sun (solar energy). Lighting was provided by plant oil and wax, and some fish oil. Mechanical work including long-distance transportation was mostly conducted by human power or to a small extent by animals. The diet was mostly vegetarian, and little use was made of meat. The energy output efficiency of meat (i.e., the ratio of energy output to the total energy input including direct solar energy and all other energy necessary) is at most one-tenth of that of cereal.

One way to measure the efficiency of energy use is by the ratio of the energy value of material produced to the energy input (excepting solar energy). For example, in rice production the energy input is the total energy used to produce a certain unit amount of rice, or rather its energy value, that is, the energy output. In the Edo period, almost 100 per cent of farming activity was carried out by human power. The implements used were not mechanical devices, but simple farming tools such as hoe, spade and sickle. The energy value required to produce such tools is negligibly small. Modern agriculture requires various kinds of mechanical devices whose production and use requires a large amount of energy. The following description is based on the work of Ishikawa (1993), who attempted to estimate the energy efficiency of various aspects of human activities in the Edo period.

First, in respect of rice production, the basis of the economy, Ishikawa made the following assumptions. On average three persons working full time for about a half year (183 days) produced 2.4 tons of rice on one hectare of land. Assuming the energy required for one day's work to be about 1,000 kcal/person, the total energy input is 5.5×10^5 kcal, and since the energy value of rice is about 3,400 kcal/kg, the total energy output is 8.2×10^6 kcal. Therefore, the energy efficiency of rice production in the Edo period can be estimated to be about 1,500 per cent, i.e., 15 times.

How about modern rice production? The Science and Technology Agency of the Japanese government estimated that the production of 1 kg of rice requires about 2,300 kcal of energy, indicating that the energy efficiency is about 150 per cent or one tenth of the Edo period. About half of this energy is required to

manufacture and use the various agricultural mechanical devices, and about one quarter for the production of chemical fertilizers, pesticides, *etc*. The issue of fertilizer in the Edo period will be discussed later. Suffice to say that the energy requirement for fertilizer in Edo was negligible.

The major difference in these two situations is human labor. Farming was very hard work in Edo and is much less so today. In other words, an enormous amount of energy has reduced the human labor in farming in terms of both farmers' work and the number of farmers. This is economically possible only because of the availability of relatively cheap energy source, i.e., fossil fuel.

The energy efficiency of fishing in the Edo period attained a similar value: the energy value of fish obtained/the energy input (human labor) was 1,000-2,000 per cent. Fishing could be done only in lakes, rivers and the sea not too far offshore since fishing boats could only be operated by human and wind power. By contrast, the energy efficiency in today's mechanized fishing industry seems to be about 50 per cent.

Until quite recently, Japanese houses had no "space-heating". Since Japan is located in a mild climate region, the severity of cold in winter is not extreme except in the North. Hence no very elaborate heating system was used in most regions. This is an advantage afforded by geography. In summer, however it is very warm and humid. The traditional houses and buildings were hence built in such a way to provide as much comfort as possible during the summer. The building material was and still is mainly wood. Because of earthquakes, brick and stone are not suitable for building, and wood also happens to be a better thermal insulator than brick and stone. The structure of the traditional Japanese houses is not suitable for space heating, being too porous and open. The traditional heating devices include "hibachi" and "kotatsu" (a foot warming device) which heat only locally those sitting nearby. People wore more clothes when cold. The other device, called "irori" (hearth) was a kind of fireplace, but it was used mainly in farmhouses. These devices may not have been as comfortable as contemporary space heating, but were very frugal in terms of energy use.

A model of a takadono, a high-roofed structure with a
furnace and foot bellows (tatara), on display at Wako
Museum in Shimane Prefecture.

The traditional procedure of iron/steel production, known as "Tatara" used charcoal as the reducing agent. It has been estimated that production of 1 kg of base iron required about 2.3×10^4 kcal, the major portion of which came from charcoal. The modern technology has reduced this energy to about 4×10^3 kcal. That is, the older technique's energy use was not very efficient. A large amount of wood had to be cut to provide the charcoal for iron production; hence the forest from which the wood was supplied was usually left to re-grow for at least 30 years before it was reused. The property of the iron/steel product from the old technology is known to be far superior to that obtained by the modern technology (Morris-Suzuki, 1994, 45-49; Tatara website).

The long-distance transportation of rice, sake and other relatively heavy items was usually

done by wind-driven boats. This very efficient system was made possible by the geographical location of Japan.

Edo Renewables

Only renewable material from plants was used; the exceptions were iron and a few other metals obtained from non-renewable resources. Other than food, plants provided material for cooking, heating (directly and as charcoal), building, furniture and other fixtures, fertilizer (as compost), oil for lighting, and so on. Today, Japan imports more than half of its lumber/pulp, *etc*. In Edo nothing was imported, yet the forested area in many regions was actually expanded.

Let us look at a few examples. The Japanese had an extensive supply of paper in the Edo period. How was it possible? Paper was made only from the annual growth portion of certain fast-growing trees. Therefore, trees were never exhausted. The method of making paper was such that the cellulose fiber used was of much longer size, about 10 mm long, than that made in the modern mechanical procedure, which is about 1 mm long. This made paper making easier and required fewer additives. The resulting paper was sturdy and yet flexible and lasts long (Washi website). This alone does not guarantee an ample supply, because the resource was, after all, quite limited. The secret was to "recycle" which is discussed below.

Publication was quite extensive in the pre-industrial Edo period. It has been estimated that the average number of publications was about 250 items per year for the population of 30 millions\ between1600 and 1850. This may be compared with the number of publications in Canada in 1952, an industrial society, i.e., 684 items. The comparison suggests the significance of the number of publications in Edo Japan. In Edo, daily newspapers were also published in the capital and a few other cities, and art works such as woodblock prints were also published extensively. This presupposes the existence of literate and cultured public, comprising not only Bushi but also townspeople and many farmers [2].

Printing in Japan has a curious history (e.g., Haga, *et al*, 1994). The oldest known printed material on paper in the world was published in Japan in the 8th century, when one million copies of a Buddhist charm (dharani) were made, apparently using a woodblock and metal etching method (Ishikawa, 1995). A printing method using movable metal type was invented in China and then (apparently independently) in Korea, and was brought to Japan in the period between the 13th and the15th century. In the 16th century the Portuguese introduced movable type printing to Japan. The Japanese used this method with movable types made of lead, and a few dozen books printed in this manner are known to exist. However, the last print using this method was made in 1611. The method was then abandoned, and Edo Japan reverted to woodblock printing. Several reasons can be suggested for this. One is the nature of Japanese writing, consisting of two sets of fifty phonetic letters plus several thousand structurally complex Chinese characters. Movable types made for such a complex writing system was cumbersome and complicated, requiring an enormous number of reserved types. It is easier to carve out letters and characters as needed on a piece of wood which can be used over and over again, with the same wood resurfaced for reuse. Thus, the material is renewable and this method is more economical and environment-friendly. This was the second reason. Especially for printing other than letters/characters, i.e., artworks, woodblock printing was both easier and more flexible than metal etching. Eventually a multicolored woodblock printing was invented and was used to print artworks, which were also made accessible to the general public.

Edo Recycling

If only renewable material is used and its rate of

production is limited by the natural growth rate, material would never become abundantly available. It appears, however, that significant numbers of people in the Edo period (with the important exception of poor farmers) generally enjoyed relatively affluent lives with a limited supply of renewable resources. How?

The answer is “recycle”, “recycle” and “recycle” (Ishikawa, 1997a). They recycled almost everything and almost exhaustively. They also repaired almost everything over and over again until no more use could be made of it. Of course, most of the devices and implements were of simple structure and construction, and hence were easy to repair unlike many contemporary gadgets.

Paper, for example, was 100 per cent recycled. It was a business to recycle or rather buy back paper products. It is said that a poor person could live off collecting paper products or just parts of them discarded on the street. In certain regions, even soiled toilet paper was collected and recycled. Being made of longer and stronger fibers (Washi website), Japanese paper could withstand reuse much better than modern paper. Likewise, most clothes recycled, as the production of fiber (mostly cotton) was limited, expensive and time-consuming.

The ash from firewood and charcoal was also collected and bought and sold as fertilizer. Some chemical compounds such as potassium carbonate were also extracted and sold. Even the candle droppings were saved, bought, reshaped and sold by a business.

Human and animal wastes were completely recycled. They were collected, bought and sold to farmers as fertilizer by business establishments. That is, such items were made a salable commodity, though some farmers purchased it directly from the consumers. The straw of rice plants was used extensively for wrapping rice and other substances, and as sandals, *etc*, and it was composted after all these uses. Likewise food waste was completely composted. Agriculture was truly “organic”. Of course, chemical (or rather synthetic) fertilizer or chemical pesticides were unknown. In some places, ammonia and nitrate were extracted from urine, and were used to make gun powder. This made unnecessary a sewage system, and did not load polluting substances on rivers, lakes and coastal seas. Edo city established an extensive system of fresh water supply, perhaps more extensive than that of London at the time.

Naturally any material containing iron and copper, no matter in what shape or condition, was avidly collected and recycled. Given these attitudes and the practice, the recycling business minimized garbage, and made easy the garbage disposal. City streets were clean without much actual “cleaning”, because almost all materials were picked up, sold, and reused.

Foreign visitors during the Edo period tended to corroborate this. Two observations may be quoted.

“Diseases caused by polluted water and imperfect sewage treatment systems in the United States are either unknown or very rare in Japan. In the US the polluted sewage water enters rivers and bays, and pollutes them, killing living organisms. Apparently, those wastes are recycled back to the soil in Japan and make it fertile, but not polluting the streams....” (Morse, 1888).

“Edo is a big city in the East...the Bay facing Edo is beautiful.... The scenery from the castle can be favorably compared to many European cities. The hills are covered with trees, and roads are lined by trees and green hedges. Its beauty is perhaps the best in the world....” (Fortune, 1863).

Edo Lessons

Over 300 years, Edo Japan flourished while taking every possible step to maintain the principles of zero-waste, zero-emission (long before such terms came to be appreciated). In

retrospect, therefore, the Edo experience may stand out in the history of world civilizations as uniquely sustainable, and therefore a greater accomplishment, with greater lessons for 21st century humanity, than the much-later, quite opposite phenomenon: the "miraculous," high-growth Japan of the 20th century. However, the Edo experience is rarely understood in those terms by comparative historians of civilization. Diamond (2005) does discuss the successful management of forests in Edo, but he does so only in terms of top-down regulation, which might better be seen as only part of the reason. Elsewhere, reference to or understanding of Edo is not common in the literature. Looking at the Edo experience as a whole, the following six factors may be considered part of the explanation.

(1) Geographical location: elaborate heating was unnecessary, and the ecology was relatively robust.

(2) Peace: there was none of the waste of human, energy and material resources associated with war.

(3) Vegetarian diet: such a diet is energy-efficient, and the environment was spared the disturbance due to grazing animals.

(4) High educational levels: the people were informed of many issues.

(5) The political system: was such as to allow a long-term view on the environment.

(6) Cultural factors: a distinctive Edo attitude toward people, nature (environment) and the world.

Of these, perhaps most contentious and controversial may be the weight to attach to distinctive cultural factors. This author plans to explore these questions in a subsequent essay.

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Notes:

[1] In early Meiji, a group of University of Tokyo professors recorded interviews with officials of the old Tokugawa regime in a work entitled *Huruki koto Tazuneshi Kiroku* (*Stories told by officials of the old regime*").

[2] The fact that even some farmers were literate and cultured was indicated by a discovery by a Japanese historian, Irokawa (1985). In a storehouse in a farming village 70 km west of Tokyo he found a collection of books, both Japanese and Western including some by John Locke and Henri Rousseau, and a draft constitution for the new Japan written by a young man at the juncture of Meiji restoration (1880s). Similar examples have since been uncovered all over Japan.

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