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Growth Experience of Japan Since WWII, and its Environmental Consequences

A Report Submitted in Partial fulfilment
of the Requirements for the Course of
HS5.201 - Growth and Development

by

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1 Introduction

1.1 Problem Statement

Choose any OECD country. Study the growth experience of this country in the period since the 2nd World War to understand the environmental impact of this growth. Based on your analysis, comment if positive growth in the next few decades is sustainable for this country.

1.2 Motivation for Choosing Japan

Japan's unique geography helped provide plenty of rainfall and strong seasonal winds, but despite this aid, it faced extreme levels of environmental damage post World War 2. After facing devastating losses in WWII, the Japanese felt compelled to pursue endeavors that resulted in its rapid growth. This negligence for the environment, coupled with corrupt politicians and profit driven corporations led to massive degradation of Japan's soil, air, and water, and even cost its population good health due to diseases that came out of this pollution.

Despite these issues, Japan's economy showed growth phenomenal growth rates in the years following the War. Japan's post-WWII recovery is remarkable despite initial setbacks, including the effects of nuclear weapons, economic sanctions, diseases that spread due to pollution, an ageing population, and declining birth rates. We want to use concepts studied in class, and explore further literature that will help make sense of Japan's growth, and along the way highlight the environmental impact that has resulted from this growth.

1.3 Project Summary

In Section 2, we will see what conditions Japan had to start off with post WWII, and the kind of growth model it initially picked. We then apply the Harrod-Domar model - a classical economic growth model to see what kind of growth rates can be determined using other available parameters. We then explore the results of Japan's economy-centric model, and study the environmental impact of such an aggressive approach. To correlate environmental impact with economic activity, we use the tool - Ecological Footprint [2].

In Section 3, we provide an overview of Japan's rapid post-World War II growth and the environmental crises it triggered. We delve into public responses through protests and their impact on shaping improved environmental policies. Then, we examine The Basic Environmental Law as an initial step towards pollution reduction and its guiding principles. Additionally, we explore some government policies and their effects on pollution levels. Finally, we discuss Japan's engagement in global environmental policies.

In Section 4, we present the current state of economic sectors of Japan such as Agriculture, Industry and Energy. Using first principles taught in class, we analyze potential environmental and sustainability issues, and find clues to answer the question of whether Japan can realise positive, sustainable growth within the next few decades.

2 Environmental Impact of Japan's Economic Growth

2.1 Conditions Japan Started With Post WWII

The Japanese invasions inflicted significant harm on cities and villages across China, the Philippines, Burma, and beyond. However, they also suffered substantial losses from American air raids and bombings, with Hiroshima and Nagasaki bearing the brunt of nuclear attacks. Radiation poisoning affected people beyond the blast zones, while food shortages led to a rise in tuberculosis cases. Inadequate water control perpetuated flooding, and over 40% of the railway infrastructure was destroyed [3]. Over 2 million people (3% of Japan's population) had died by the end of the war [4].

Many social issues arose as well. The overall Japanese moral was down due to the aftermath of the war, and especially due to the atomic bombings. More than 1 million children had been displaced from cities to the countryside [4]. The survivors of the atomic bombings (called the Hibakusha) were also discriminated against due to lack of awareness.

2.2 Japan's Economic Growth

Despite the bad start, Japan's aggressive efforts helped make it the world's second largest economy by the year 1967 [5]. A large part of this success can be attributed to the U.S. as they did not want Japan to fall under Soviet influence.

2.2.1 Growth Strategy Pursued

Japan's new economic model led to a boom in the economy, and results of it are sometimes referred to as the 'Japanese Economic Miracle'. It is characterized by rapid growth from 1945 to the early 1970s. Aspects that supported this growth were technological advancements, increased quantity and quality of labour and more international trade [6, 7].

- Under influence of the United States, many military, political, economic and social reforms were made during what is known as the 'occupation of Japan' between 1945 and 1952. Their military was made powerless, and officials were not allowed to take up political roles. Land reforms were established to help bridge the gap between tenant farmers and land owners.
- The Japanese made use of the fact that most of the technology they possessed was destroyed in the war. They adopted cutting edge instruments and technology without worrying about old machinery depreciating. They also imported new technology and upgraded it to be approximately 20% more efficient.
- Japan focused on investing in manufacturing industries and improving their technologies. Their high productivity led to large returns, which would have resulted in high inflation. To combat this, the rate of personal savings was also high. The ratio of personal savings to disposable income averaged at 18.3% in Japan during 1959 and 1970, compared to 12% in Germany and 7% in the United States.

- Japan also sought after a strong foreign policy and opened its doors for international trade. America helped with this agenda by subsidizing the Japanese economy, and 'absorbing' Japanese exports [8]. Other factors like the outbreak of the Korean war in 1950 led to a high demand for Japanese goods [9].

2.2.2 Analysis of Japan's Growth under the Harrod-Domar Growth Model

In the Harrod-Domar Growth Model, investment is treated as two concepts - one in which it tells us the demand in the short run, and the other in which it is a measure of the production factor in the long run [10]. The GDP Y can be calculated as the sum of the consumption C, investment I, government expenditure T,

$$Y = C + I + T$$

Here, given that S = savings, c = average and marginal propensity to consume, s = average and marginal propensity to save, t = average and marginal tax rate, we can say that

$$C = c(Y - T) = c(1 - t)Y$$

and, since $c + s = 1$,

$$S = I = s(Y - T) = s(1 - t)Y$$

We also have,

$$T = tY$$

The Harrod-Domar model assumes that the increment in capital stocks is the same as the value of investment. Taking K = capital stock, λ = capital coefficient (constant),

$$K = \lambda Y$$

, which implies that

$$\lambda = \frac{K}{Y}$$

We know that investment I = change in capital stock, and therefore, $I = \Delta K = \lambda \Delta Y$

This gives us the growth rate expression,

$$G = \frac{\Delta Y}{Y} = \frac{1/\lambda}{Y} = \frac{s(1-t)Y/\lambda}{Y} = \frac{s(1-t)}{\lambda}$$

Now, from [10, 11], we get the following table. We will need the tax values from this table (See Fig 1).

Now we will use the following table from the same study, and see if our Harrod-Domar model fits (See Fig 2).

	1955	1960	1965	1970	1975	1980
Tax Revenues / NI	19.2	19.2	18.4	19.3	18.9	22.8
Social Security Contribution / NI	3.3	3.6	5.0	5.4	7.5	9.1
Social Security Transfer / NI	5.4	4.5	5.9	5.8	9.5	12.5
Public Expenditures / GDP	18.0	15.2	17.2	15.6	19.3	19.3
General Account Budget / GDP	11.8	10.4	11.0	10.9	13.7	17.7
FILP / GDP	3.5	3.7	5.3	5.0	6.9	7.4
FILP / General Account Budget	29.2	35.9	47.7	46.4	50.6	41.7

Figure 1: Japan Tax Statistics

	1951-56	1956-61	1961-66	1966-71	1971-76
growth rate	7.8%	10.1%	9.2%	10.9%	5.0%
capital coefficient	2.8	2.9	3.4	3.2	6.5
savings rate	28.0%	29.6%	31.8%	34.4%	32.6%

Figure 2: Growth Rate, Capital Coefficient, Savings Rate of Japan

Now we will calculate the Growth rate values as given by the Harrod-Domar model

$$G_{1951-56} = 28 * (1 - 0.192)/2.8 = 8.08$$

$$G_{1956-61} = 29.6 * (1 - 0.192)/2.9 = 8.25$$

$$G_{1961-66} = 31.8 * (1 - 0.184)/3.4 = 7.63$$

$$G_{1966-71} = 34.4 * (1 - 0.193)/3.2 = 8.68$$

$$G_{1971-76} = 32.6 * (1 - 0.189)/6.5 = 4.07$$

These values, compared to the actual ones in the table are fairly close, which indicates that our growth model gave a decent estimate!

2.2.3 Result of Japan's Growth Strategy

The bar graph below shows how Japan's real economic growth rate has consistently increased from the 1950 to 1970 [6] (See fig 3).

We see a period of rapid economic growth till 1970. This growth increase reduces drastically during the 1973 oil crisis.

One useful measure of spending of a country is the Gross National Expenditure (GNE). GNE

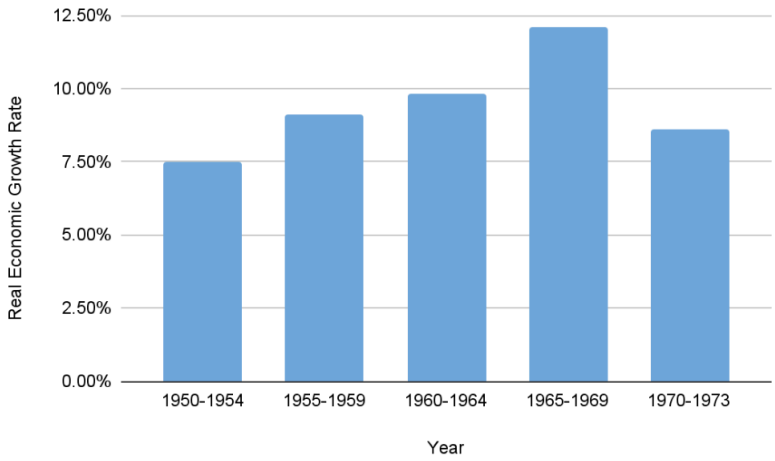

Figure 3: Real economic growth rate across years

at constant prices is the same as Real GNE. It is given by the sum of the household and government final consumption expenditure, and gross domestic investment [12]. If we see Japan's GNE at constant prices over the years, then we see a sharp decline during the end of the war, after which it takes almost a decade to reach its pre-war value [13](See fig 4).

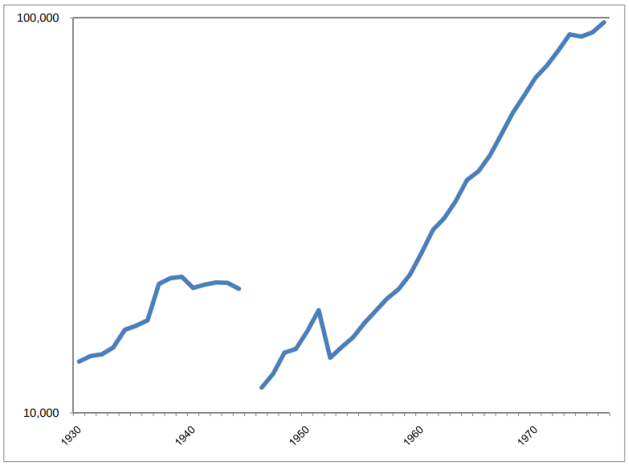

Figure 4: GNE at Constant Prices, Japan: 1934-36 calendar year base, in million of yen; after 1952, 1970 calendar year base, in billions of yen

While 'growth' is certainly visible in these plots, it is not easy to tell which sector is contributing the most to this growth (especially since data in the post-war period is not as well compiled as data post 1990s). To get a feel of this, we can observe how the agriculture and manufacturing industries add to the Net Domestic Product (NDP) over the years (See fig 5). In the early 1930s, agriculture contributes to more than 20% of the NDP. Then we see a rise in this contribution till the year 1944, which can be attributed to the militarization that took

place during the war. After Japan's loss, and under its new growth policies, manufacturing takes a lead, and after 1956 it contributes to a greater percentage than what agriculture does. These findings are consistent with the growth model explained in the section above.

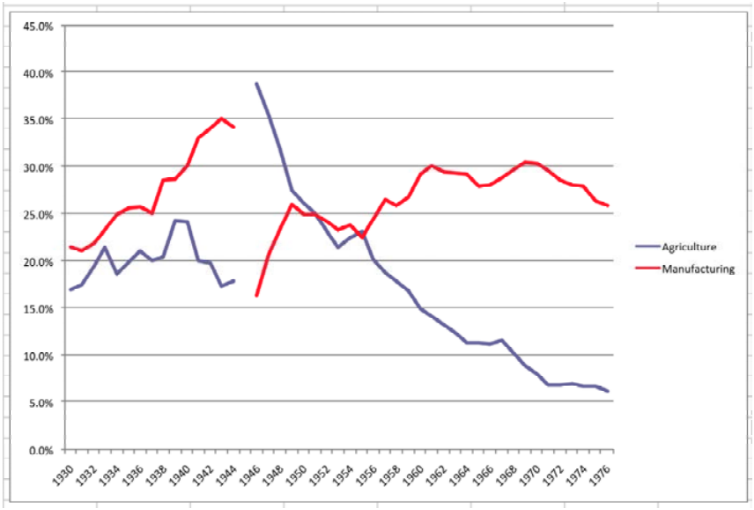

Figure 5: Shares of Agriculture and Manufacturing in adding value to NDP, Japan 1930-76: In millions of yen until 1944; in billions of yen after 1946

To really grasp this economic 'miracle', we can see how Japan's Real GDP Per Capita grew in contrast to that of the US and Britain [14] (See fig 6).

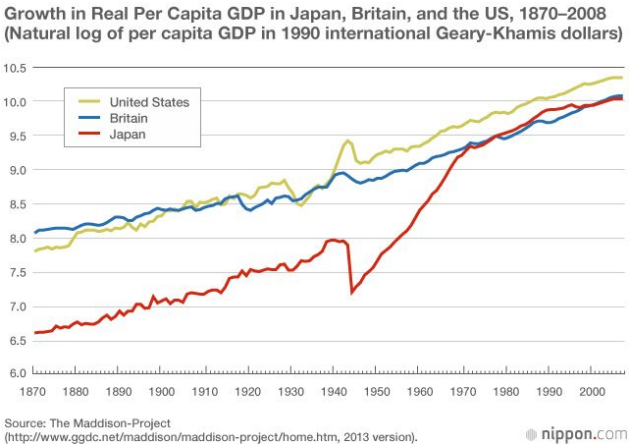

Figure 6: Growth in Real GDP Per Capita (logscale) of Japan, Britain, US from 1870 to early 2000s

2.3 Environmental Impact

Following World War II, Japan confronted substantial environmental challenges arising from rapid industrial expansion, domestic market growth, and aggressive export policies, a problem

made worse by its limited access to natural resources.

1. Air Pollution: During the initial phase of post-war economic growth in the 1950s, coal-fired energy production caused significant air pollution, with inadequate dust control measures leading to widespread emission of black smoke.
2. Industrial Pollution: The proliferation of factories concentrated pollutant sources, giving rise to severe pollution-related diseases such as Minamata disease and Yokkaichi asthma.
3. Water Pollution: Rapid industrialization post-WWII led to serious water pollution issues, stemming from various industrial activities.
4. Lack of Environmental Awareness: A societal focus on modern lifestyles overshadowed concerns for environmental preservation and human rights, exacerbating environmental problems.
5. Urbanization and Land Reclamation: Accelerated urbanization and land reclamation further degraded the natural environment, generating vast amounts of industrial and domestic waste.

While it is obvious that factors like air/water pollution 'increase' due to industrialization, it is hard to connect it to economic activity if we only talk about the increase in pollutant levels. This is why we referred to studies that measured environmental impact using measures like 'ecological footprint'.

2.4 Ecological Footprint as a measure of Environmental Impact

2.4.1 What is Ecological Footprint?

The study [2] uses the tool - Ecological Footprint (EF) as a measure to determine how much humans depend on natural resources. More formally, it provides a measure of the habitat/space used to support the lifestyle of a society given its current technological capabilities. It takes common goods that are consumed by the society and converts these goods into the amount of cropland, pasture land, aquatic area, forest area, energy land and degraded land used to support its consumption. It is like the aggregate amount of land (area) required to continuously produce a set of resources, wherever the land may be located (this point is important while considering goods that are imported/exported).

For example [2], if 12% of each land category is allotted for natural purposes (example for biodiversity), then 88% of it can be assigned to support our human society. Estimates say that this land was 3 hectares per capita in 1965, but had reduced to less than 2 hectares per capita in 1995. Our globe has crossed this consumption limit in 1993 itself.

The ecological footprint serves as a tool to assess the overall environmental impact of a society and also offers a method to evaluate specific programs, policies, or technologies in terms of their environmental implications.

2.4.2 How is Ecological Footprint Calculated?

All available land is categorized into distinct types, including Crop Land, Pasture Land, Forest Land, Degraded Land, Energy Land, and Productive Oceans. Subsequently, a thorough analysis of major goods is conducted, with their impact estimated based on the tonnage consumed. Consumption levels are determined using production and trade data. To gauge total consumption accurately, national production is adjusted by deducting exports (as they are consumed elsewhere) and adding imports (as they are produced elsewhere).

For instance, consider the case of fish: Fish meal, derived from fish by-products, serves as a vital protein source for animal feed in Japan. It is considered a secondary use rather than the primary use of fisheries resources. This approach prevents double counting by allocating the land area required to supply multiple goods to the most significant product, thus ensuring accuracy in the study's findings.

2.4.3 The Ecological Footprint of Japan

The article [2] states that from 1961 to the mid 1990s, Japan's EF has nearly doubled from 3.4 hectares per capita to 6.3 hectares per capita. Meanwhile, Fair Earth share available to each person has gone down from 3 to 2 hectares.

If we look at the percent change in EF per capita (every year), then we get the following figure 7.

	1960s	1970s	1980s	1990s
real GDP per capita	10.2	3.3	3.5	1.0
ecological footprint per capita	5.5	0.4	1.1	0.9
EF/GDP ratio	.54	.14	.32	.87

Figure 7: Annual Growth Rates of GDP and EF (per cent change per annum)

One observation we can make is: that we want this number EF/GDP ratio to be as low as possible. But it is important to note that there is some delay in implementing policies and seeing the results of those strategies. For example, a policy that was come up with in the 1990s may see its fruits only in the 2000s.

It is also important to note that EF has its own drawbacks. For example, EF does not take care of pollution involving radiation, toxic chemical waste, and non-renewable energy consumption.

3 A Shift Towards Better Environmental Policies

3.1 Introduction

The years following the World War II, Japan experienced tremendous economic growth. This period, often referred to as Japan's economic miracle [6], saw Japan rapidly becoming the world's second-largest economy behind the United States. This economic boom can be attributed to the immense industrial and urban development during this time. Japan prioritized economic growth at all cost, disregarding the environmental and social conditions. This unchecked development resulted in environmental disasters such as Minamata disease, Itai-itai disease and Yokaichhi asthama which took a significant toll on lives and degraded the environment [15].
Japan's environmental policies can be divided into three periods:

1. **1945-1970:** The period of rapid economic growth and unchecked pollution
2. **1970-1989:** Introduction of environmental laws and their enforcement
3. **1990 onwards:** Focus on environmental policies (national and international)

In the following sections, we will examine Japan's transition toward improved environmental policies following the environmental disasters mentioned above.

3.2 Citizen and administrative response to environmental problems

The environmental crisis in post-Second World War II Japan prompted significant public outcry and sparked grassroots movements demanding change [16]. These environmental movements included a diverse mix of old conservationists, young ecologists, former socialists, and local activists protesting against increasing environmental destruction. Citizens and workers alike mobilized against the irresponsible practices of corporations and government bodies, which prioritized profit over environmental concerns. These movements, fueled by concerns over human rights and the detrimental impact of pollution on communities, gained momentum throughout the 1960s. From organizing protests against H-bomb tests to resisting the construction of polluting petrochemical complexes, the public exhibited a growing awareness and determination to hold corporations and government accountable for their actions. The victims of pollution diseases, such as Minamata disease and Yokkaichi asthma [17], played a pivotal role in these movements, taking their cases to court and demanding compensation for the damages inflicted upon them . Their activism led to legal victories and increased public awareness of environmental issues. The pressure from these movements ultimately forced the government to acknowledge the severity of the environmental crisis and enact policies aimed at addressing pollution and promoting sustainable development.

3.3 The Basic Environmental Law

As a consequence of several environmental movements and anti-pollution protests, the Japanese government had to acknowledge and take responsibility for the major environmental disasters. In response to the severe environmental pollution stemming from rapid industrialization, and urbanization, The Basic Law For Environmental Pollution Control was passed in 1967. It was among the first "basic laws" in Japan, stating basic policy frameworks such as the role of different actors. This law encompassed the following three environmental principles:

1. The first principle recognizes the vital link between the environment and human survival, acknowledging the finite nature of environmental resources and the delicate balance of ecosystems.
2. The second principle stresses on the collective responsibility of all sectors of society in safeguarding the environment, advocating for a balanced approach to social and economic development that promotes sustainable growth while minimizing environmental strain.
3. The third principle highlights Japan's commitment to international cooperation in addressing global environmental challenges. It emphasizes the importance of leveraging Japan's economic and technological resources to promote conservation efforts and advance sustainable development on a global scale.

The Air Pollution Control Law was enacted in 1968, followed by the Natural Environment Conservation Law in 1972. The Japanese Environment Agency (JAE) was established in 1971. By the 1980s Japan had successfully reduced the critical pollution levels significantly. However, during the steady growth of 1980s, Japan experienced a surge in mass production, consumption and waste generation. Simultaneously, rural forests and farms encountered significant challenges. Reports suggest that even after significant improvement in air quality, water quality and energy efficiency, the environmental condition of Japan was still poor [15]. The laws enacted in the 1970s were successful in addressing the environmental issues, but they fell short as new problems emerged. These "policies of yesterday" tackled "yesterday's problems" but were unable to address global environmental problems, urban population, loss of accessible environment due to rapid urbanization. Hence, the Basic Environmental Law was passed on 13th November, 1993 to address these new challenges.

3.4 Environmental Initiatives and Policy Implementation

The government-led initiative to address environmental degradation and pollution catalyzed a series of responses across Japanese industries and other ministry agencies [18]. This concerted effort led to the formulation of numerous policies aimed at improving water and air quality, preserving flora and fauna, and reducing industrial waste. Here are some key policies implemented and their effect:

1. **Water quality:** Tighter effluent standards and better wastewater treatment led to significant reductions in water pollution levels in rivers, lakes, and coastal areas [1]. The

Total Pollutant Load Control systems allowed authorities to more effectively manage and limit the overall discharge of pollutants into water bodies. This can be observed in Figure 8. Improved water quality restored aquatic ecosystems and aided in the recovery of fish and marine species. Tighter regulations on industrial wastewater notably reduced heavy metal levels in Japan.

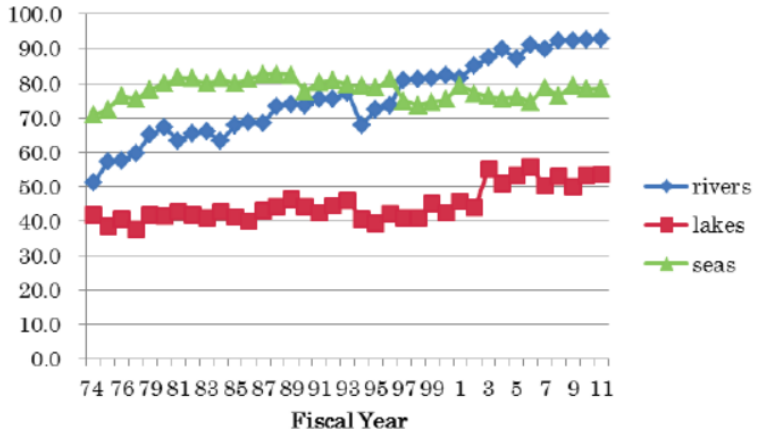

Figure 8: Achievement Rate of the Environmental Quality Standards (Biochemical Oxygen Demand or Chemical Oxygen Demand) in Japan [1]

2. **Air quality:** Stricter vehicle emission standards and industrial pollution controls reduced levels of air pollutants like sulfur oxides, nitrogen oxides, and particulate matter [1]. The shift towards cleaner fuels and technologies lowered emissions and improved air quality, especially in urban centers. The impact of these policies can be observed in Figure 9. This had positive impacts on public health, reducing the incidence of respiratory illnesses and other air pollution-related problems. In alignment with its clean energy strategy, Japan aims to achieve the goals of carbon neutrality by 2050 and a 46% reduction in greenhouse gas emissions in fiscal 2030 [19].

3. **Flora and fauna:** Expansion of protected natural areas and conservation efforts helped preserve habitats and biodiversity. Programs to control invasive species and restore native ecosystems enabled the recovery of many threatened plant and animal species [20]. The protected areas also provided important recreational and tourism benefits for the public.

4. **Industrial waste:** Stronger regulations and the promotion of the 3R approach led to significant reductions in industrial waste generation and higher recycling/recovery rates. This shift in policies extends beyond pollution control to prevention and embraces dematerialization technologies, which prioritize efficiency by reducing material and energy consumption per unit product [18]. In November 1990, the Experts' Study Committee on A Recycle-Oriented Society for Environmental Protection, operating under the Japan Environment Agency (JEA), released a report that paved the way

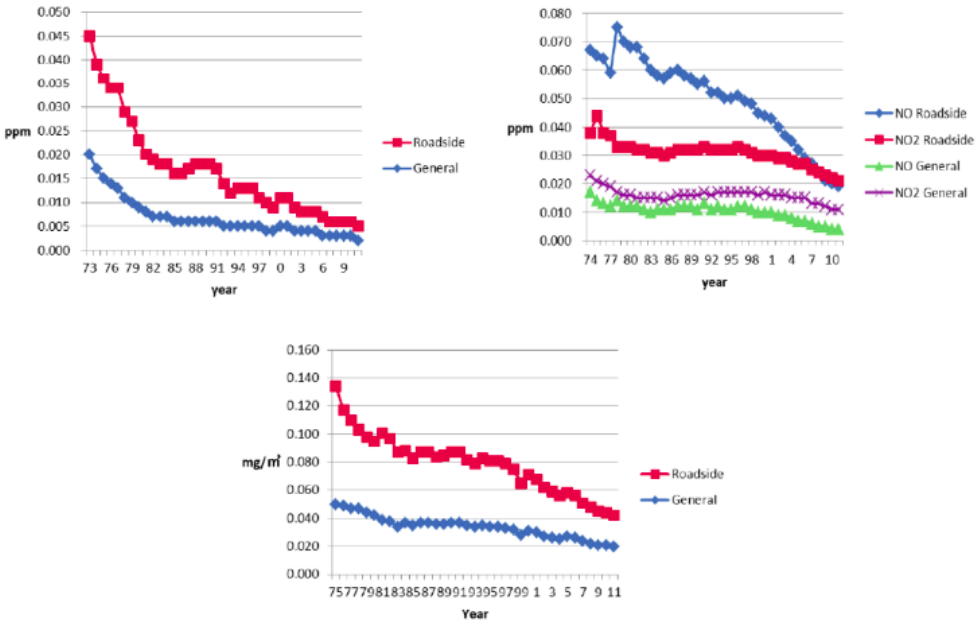

Figure 9: Changes in the Annual Averages of SO2, NO, and suspended particulate matter [1]

for Japan's 1991 recycling law. In April 1990, Keidanren, a federation representing over 1,000 private industry and business organizations, published a document outlining the industry's stance on new environmental policies. This marked a significant shift, as Japanese companies were mandated for the first time to assess all their activities with the goal of reducing their overall environmental impact [18]. Organizations and leading firms in Japan were mandated to integrate environmental precautions into their operations at all levels, aligning with a government document. Concurrently, the Japanese government intensified its environmental public policy efforts. Advanced waste treatment and disposal technologies were implemented to mitigate environmental impacts [1]. The outcomes of these policies can be seen in Figure 10. These initiatives resulted in reduced pollution of soil, groundwater, and surface water from industrial waste.

5. **Technological Advancements:**
   Technological advancements have bolstered efficiency in the energy sector, supported by consumers and other users [1]. These measures have contributed to a reduction in pollution levels. The outcomes of these advancements are evident in Figure 11.

3.5 Japan's role in global environmental policies

Japan has demonstrated proactive engagement in addressing international environmental issues, driven by the recognition that its environmental conditions are interconnected with

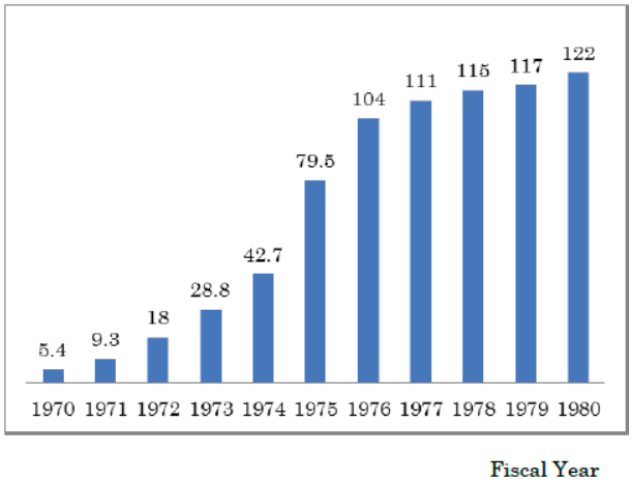

Figure 10: Capacity of SOx Removal Facilities (Million Nm /h) [1]

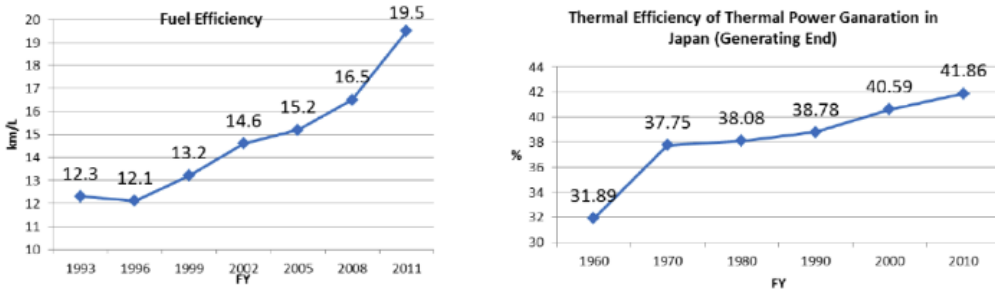

Figure 11: Fuel Efficiency of Passenger Vehicles (10-15 modes) and Thermal Efficiency of Thermal Generations [1]

those of other countries [20, 15]. As a result, Japan has taken proactive steps to participate in global environmental policies, seeking collaborative solutions to safeguard its national interests and promote global sustainability. Japan has been involved in numerous international treaties and policies, but for brevity, we focus on select ones in this discussion. Below are some policies in which Japan has actively participated:

1. **United Nations Environment Programme (UNEP):**
   UNEP, as the designated United Nations body responsible for tackling environmental issues on a global and regional scale, holds a pivotal role in facilitating the formation of consensus on environmental policy. Japan has actively supported UNEP's work through contributions to the Environment Fund and the International Environmental Technology Centre (IETC), among other initiatives. In addition to its annual voluntary contribution to the Environment Fund, Japan provided substantial support for a UNEP project aimed at reducing marine plastic litter in Southeast Asia and India, amounting to 1.1 million US dollars in 2019 [21]. Since its inception, Japan has been a member of the UNEP Governing Council, demonstrating its commitment to global environmental stewardship.
2. **Kyoto Protocol:**
   The Kyoto protocol is an international treaty that builds up on the United Nations Framework Convention on Climate Change (UNFCCC). It obligates the participating countries in reducing their greenhouse gas emissions. The protocol was formally adopted in Kyoto, Japan, on December 11, 1997, and came into effect on February 16, 2005.
3. **Montreal Protocol:**
   The Montreal Protocol is a global treaty established in 1987 to safeguard the ozone layer by eliminating the production of various substances that contribute to its depletion. It came into effect on January 1, 1989. Climate forecasts suggest that the ozone layer will recover to its 1980 levels by 2040 in many regions and by 2066 in Antarctica [22].

4 Present-Day Struggles in Japan

We present a brief overview of Japan's current standing in the spectrum of world's economy.

- Japan boasts a highly developed social market economy, positioned as the world's fourth-largest by nominal GDP and by purchasing power parity (PPP).
- Japan is also the fourth-largest importer and fifth-largest exporter worldwide [23, 24, 25]. It holds the second-largest foreign-exchange reserves at $1.4 trillion and is noted for its significant global financial influence [26].
- The nation leads in technological innovation and manufacturing, especially in high-tech and precision goods like integrated circuits, hybrid vehicles, and robotics [27].
- Japan's automotive industry is the second-largest globally [28].

- Despite its economic might, Japan faces challenges from demographic shifts, notably an aging and declining population, projected to fall below 100 million by the mid-21st century [29, 30].
- Japan's public debt is remarkably high, approximately 260% of GDP, posing further challenges to economic stability [31]. The economy is forecasted by metrics such as the Bank of Japan's Quarterly Tankan survey and is a leading global creditor, reflecting its expansive economic footprint [32, 33].

Given Japan's economic and environmental status quo, we want to infer whether positive (sustainable) growth is possible within the next few decades. We do so by presenting an incisive analysis of the following three sectors:

- Agriculture
- Industry
- Energy

The rationale behind selecting these three specific sectors over any others [1] can be attributed to the following factors: (1) direct influence on the country's economy (2) pernicious influence on the economy following environmental issues related to it.

As a direct consequence of above, two kinds of sustainability issues will be identified during the analysis:

1. **Type I issues** - sustainability issues with the sector itself denoted by $\mathcal{T}_1$.
2. **Type II issues** - sustainability issues vis-à-vis environment denoted by $\mathcal{T}_2$.

We hypothesise the answer to our problem to be a function of $\mathcal{T}_1$ and $\mathcal{T}_2$.

4.1 Agriculture

The health of a traditional economy is determined by how its agricultural sector performs [34]. Even for developed countries, it serves a key indicator of economic growth, provides insights into the nature of growth and whether it is sustainable in the future. Therefore, we present a non-exhaustive analysis of the current state of Japan's agricultural sector through an environmental lens. General remarks regarding potential sustainability issues with the sector itself will also be made.

Agriculture in Japan mainly incorporates forestry and fishing. It plays a crucial yet modest role in Japan, contributing approximately 1.1% to the national GDP as of 2017 [35].

- With only 12% of the nation's land deemed suitable for farming [36, 37], Japan has developed intricate terrace systems to maximize agricultural output in limited spaces.

[1] As an example, we could have chosen the service or the tourism sector for our analysis, but both have little to no impact to environment, making them impertinent to our problem statement.

This innovation has positioned Japan among the highest in the world for crop yields per unit area.

- The country achieves an agricultural self-sufficiency rate of about 50% on less than 56,000 square kilometers of cultivated land [38].

Despite its efficiency, the Japanese agricultural sector remains both highly subsidized and protected. The government's policies support small-scale farming over the large-scale agricultural operations common in North America [36]. The aging demographic of farmers and the scarcity of successors **pose significant challenges to the sector's sustainability** ($\mathcal{T}_1$) [39].

Rice significantly shapes Japan's agricultural sector, comprising the vast majority of its cereal production and benefiting from exceptionally high protective tariffs of 777.7% [37, 40]. As the world's second-largest importer of agricultural goods [41], Japan demonstrates a heavy reliance on foreign markets for approximately half of its grain and fodder, as well as 50% of its meat supply [42]. **This dependency poses sustainability challenges, particularly in terms of food security and vulnerability to global market fluctuations** ($\mathcal{T}_1$).

Japan's stringent import regulations have fostered a robust domestic agricultural sector, particularly in the cultivation of products like mandarin oranges and apples, which are largely grown within the country due to these restrictions [43, 44]. While this policy supports local farmers by protecting them from international competition through heavy tariffs, it raises significant concerns about its sustainability in the long term. The reliance on such protective measures may not be tenable indefinitely, potentially affecting biodiversity and the resilience of Japan's agricultural practices amidst environmental changes like climate change. Though beneficial in the short term, but this strategy could **pose challenges to the agricultural sector's future viability and adaptability** ($\mathcal{T}_2$).

4.1.1 Fishery

The fisheries sector is a major component to Japan's agricultural framework, with Japan historically ranking as one of the top nations in global fish capture [45].

- Despite a notable decline in total catch from the peaks of the 1980s and 1990s, the country's fishing industry remains vast and varied, encompassing everything from coastal to deep-sea operations [46].
- In 2005, Japan harvested over 4 million metric tons of fish, a figure that underscores the ongoing challenges related to fluctuating fish stocks [47].
- Marine and freshwater aquaculture are widespread across Japan's 47 prefectures, contributing significantly to the national supply of seafood such as sardines, skipjack tuna, crab, shrimp, salmon, trout, and eel [48, 49].

However, the sustainability of these practices is under scrutiny. Japan's extensive fishing fleet, responsible for nearly 15% of the global catch, has been criticized for its role in depleting fish stocks, including species like tuna [50]. Japan's involvement in quasi-commercial whaling has

also triggered international controversies, highlighting ethical and environmental concerns [51, 52]. These activities not only threaten marine biodiversity but in turn also **raise food security-related questions, and the long-term viability of Japan's fisheries sector** ($\mathcal{T}_2$).

4.2 Industry

Industry [2] is also one of the key determinants for an economy to have high growth. Specifically, technological progress, of which industrialization is one of the consequence of, is attributed as the cause for high growth according to the Endogenous growth theory [53, 54]. Ergo, it becomes of paramount importance to analyze sustainability issues pertaining to the Industry sector. A brief summary of the Industry sector of Japan follows.

- Japan's industry, known for its diversity and advanced sectors, significantly contributes to the nation's economy, making up 30.1% of the GDP as of 2017 [35]. The manufacturing output of Japan ranks third worldwide [55].
- Japan excels in fields such as consumer electronics, automobile manufacturing, semiconductors, and optoelectronics, facing stiff competition from global entities in the USA, South Korea, and China [56].
- The automotive sector is especially notable, with Japan being the third-largest automobile producer globally. Companies like Toyota lead as the world's largest car manufacturers, while other Japanese brands such as Nissan, Honda, Suzuki, and Mazda are also significant players [57, 58].
- Despite being a global leader in the aforementioned sectors, both the importation of natural resources and consumption of fossil fuels, ranks as the second largest net importer of fossil fuels worldwide [59].

The quantum leap of progress in the industry sector has its own caveats: keeping up with the waste produced in the industrial and manufacturing process. We highlight few potential waste management issues present in Japan.

Waste Management: Japan's waste management system is a prime example of the challenges and advancements in industrial sustainability. The country incinerates approximately two-thirds of its municipal waste. This practice historically positioned Japan as the G20 nation with the highest levels of dioxins: a harmful environmental pollutants produced by burning waste. This **highlights significant sustainability issues within the industrial sector, concerning both public health and environmental integrity** ($\mathcal{T}_2$). Though recent technological have been able to address these concerns by drastically reducing the dioxins emissions and thus mitigating its environmental impact [60], it is not warranted to be future-proof and keep up with the rapid pace of technological and industry manufacturing.

[2] We use Industry sector as an umbrella for both Industry and Manufacturing sector.

Electronic Waste: Despite pioneering electronic waste recycling programs, Japan struggles with e-waste management. In 2013, only 24-30% of e-waste was processed through formal recycling channels. The unprocessed e-waste **poses both environmental hazards and financial losses due to the untapped recovery of valuable materials** ($\mathcal{T}_2$) [61]. Moreover, much of the e-waste is exported to neighboring countries for disposal, which **raises concern about the disposal methods uncertainty, and therefore of the sector** ($\mathcal{T}_1$) [62]. In spite of the ongoing improvements in recycling technology and policies, significant challenges remain in safely managing the rising volume of e-waste.

In general, Japan maintains one of the highest recycling rates in Asia, and yet there is a significant gap in the recycling of home appliances and small electronics. Less than a sixth of such waste is collected for recycling annually [63]. This disparity has spurred new initiatives aiming to improve recycling rates and develop more sustainable waste management solutions.

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4.3 Energy

> The natural growth rate is the maximum rate of growth allowed by the increase of variables like population growth, technological improvement and growth in natural resources.

Roy Harrod on the convergence issue of the Solow-Swan model of growth [64, 65].

After thoughtful consideration, it becomes apparent that both Harrod's assertion and the concept of the natural growth rate ring true. The natural growth rate represents the highest feasible rate of growth that would lead to the full utilization of resources within the economy.

The foregoing argument provides a persuasive reason to analyze energy, a key natural resource as a part of our study. We now give a brief overview of Japan's energy sector and highlight $\mathcal{T}_1$ and $\mathcal{T}_2$.

- In 2005, Japan's energy production was heavily reliant on petroleum, accounting for half of its total energy, followed by coal at 20%, and natural gas at 14% [66] ($\mathcal{T}_2$).
- Following the Fukushima Daiichi nuclear disaster, there has been a significant shift in public sentiment towards nuclear power, leading to the shutdown of the last 50 nuclear plants by September 2013 [67]. Though few reactors have been restarted to reduce dependence on LNG imports [68], **the shutdown of nuclear plants poses sustainability issues** ($\mathcal{T}_1$, $\mathcal{T}_2$) given nuclear power is the cleanest source of energy.
- Currently, about 84% of Japan's energy needs are met through imports, making it **the largest importer of liquefied natural gas globally, and a major importer of coal and oil [69, 70]** ($\mathcal{T}_1$, $\mathcal{T}_2$). The country is diversifying its energy sources to reduce its heavy reliance on imports [57]. Despite past energy shocks, Japan has managed to decrease its petroleum dependency from 77.4% in 1973 to 43.7% by 2010, increasing its use of natural gas and nuclear power [71]

- Japan is investing heavily in global LNG projects to boost the market and ensure energy security, committing $10 billion to such initiatives as of September 2019 [72]. Renewable energy sources like hydroelectricity and solar power are also significant, with the solar market experiencing rapid growth [73, 74]. The introduction of mass-produced hybrid vehicles and the use of liquefied natural gas in public transportation are part of Japan's strategy to improve fuel economy [75, 76].

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5 The Future?

We have observed that the policies implemented by Japan have been able to address the environmental problems and reduce pollution levels significantly. However, these policies fail as the country progresses and new challenges arise. We also looked at many sustainability issues present with its fundamental sectors like agriculture, industry and energy. Considering Japan's history of swiftly adjusting policies as necessary, we maintain optimism that many of these issues will be effectively addressed.

Nevertheless, given the issues discussed and the non-exhaustive nature of our analysis inter-alia, fully ascertaining a positive and sustainable growth rate for a horizon of time as large as decades, is not viable.

6 Conclusion

In this project report, we examined Japan's post-World War II conditions and its initial growth model, applying the Harrod-Domar model to estimate growth rates. We explored the environmental impact of Japan's economy-centric approach, using the Ecological Footprint tool. We also discussed Japan's rapid post-war growth, the resulting environmental crises, public responses, and governmental policies to mitigate pollution. Then, we analyzed the current state of Japan's economic sectors, addressing potential environmental challenges and the prospects for sustainable growth. Lastly, based on the studies read, we give our opinion on how things might play out in the future.

7 Author Contributions

All authors contributed equally to sections 1 (Introduction), 5 (The Future?), and 6 (Conclusion). Section 2 was done by Aryaman Manish Kolhe. Section 3 was done by Ishan Kavathekar. Section 4 was done by Aaryan Ajay Sharma.

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