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Have International Sanctions Impacted Iran's Environment?

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Abstract: Economic sanctions have been actively used against Iran in the last four decades. In response to sanctions, Iran has adopted a range of survivalist policies with notable environmental implications. This study provides the first extensive overview of the unintended environmental impacts of international economic sanctions on Iran. It is argued that while sanctions are certainly not the root cause of Iran's major environmental problems, they have had an undeniable impact on Iran's environment by: (1) restricting its access to technology, service, and know-how; (2) blocking international environmental aid; and (3) increasing the natural resource-intensity of its economy. Sanctions have effectively limited Iran's economic growth and its ability to decouple its economy from natural resources, thereby growing the role of natural resources in Iran's political economy. Overall, sanctions have made economic production much costlier to its environment, which is not currently considered a priority in the policy agenda of the Iranian leaders who manage the country in survival mode while aggressively pursuing their ideology. The study calls for increased attention to the overlooked environmental impacts of sanctions on Iran with major health, justice, and human rights implications that could be transgenerational and transboundary.

Keywords: sanctions; Iran; environmental policy; environmental justice; environmental security; environmental economics; environmental diplomacy; unclear program; nuclear deal; JCPOA

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1. Introduction

With the presumed ability to normalize behavior and remove threats, international economic sanctions have been in use for decades. Countries, coalitions of nations, and intergovernmental bodies impose sanctions on the states that, in their view, behave abnormally according to international norms and act as threats to their interests. In theory, and compared to wars, economic sanctions do not have immediate and noticeable destructive and deadly impacts. As such, they appear as humane and soft foreign policy tools that can achieve their purpose by solely targeting the economy of the sanctioned state. In practice, however, the impacts of economic sanctions can go beyond the economic sector [1].

Sanctions can be associated with major collateral damage to ordinary citizens and their economic welfare [2–6]. The degeneration of human rights and the emergence of food and health insecurity problems as the result of sanctions are among the frequently used humanitarian grounds to criticize the legitimacy and effectiveness of sanctions [7–16]. The environment is another sector that could be impacted by economic sanctions [1,17–22]. Nevertheless, investigations of the short-term and long-term environmental implications of international economic sanctions are very limited.

The Islamic Republic of Iran (hereafter, Iran) has been the target of major international economic sanctions by the United States, United Nations (UN), and European Union (EU) over the past four decades [23,24]. Whether these sanctions have achieved their objectives and whether they have been successful in changing Iran's behavior by impacting its economy have been the subject of controversial debates. Nevertheless, the implications of economic sanctions on Iran have gone beyond the country's economic sector [15,25–29] and can have lasting impacts even when the sanctions are lifted [17,30].

Iran is currently experiencing major environmental problems. Increasing water shortage, drying rivers, wetlands, and aquifers, air and waste pollution, soil erosion, deforestation, desertification, sand and dust storms, land subsidence and sinkholes, wildfires, and biodiversity losses [21,31–39] are some of the evident signs of Iran's environmental degradation over the last four decades. Iranian top officials have frequently blamed economic sanctions for their environmental implications, some claiming that sanctions have caused "severe" and "irreparable" damages to Iran's environment [40–43]. Nonetheless, these claims have not been verified and knowledge on the possible impacts of economics sanctions on Iran's environment [17,20,44,45] is highly restricted.

2. Research Objective and Scope

The main objective of this study is to provide the first overview of the collateral environmental harms of the international economic sanctions imposed on Iran. Relying on a range of evidence, the study illustrates how economic sanctions on Iran have been associated with unintended environmental consequences. However, in interpreting the study findings, one must note the following important points:

1. This study does not examine if economic sanctions are effective in reaching their short-term and long-term design objectives. The discussion on the effectiveness of sanctions in altering Iran's behavior in comparison with alternatives such as war and diplomacy is not the subject of this study.
2. This study does not argue if economic sanctions against Iran must be lifted, continued, or tightened based on their environmental impacts. Such an argument requires a more comprehensive assessment of sanctions and is outside of the scope of this study. Impacts on the environment are among the several categories of the sanctions' impacts. Making a judgement about the overall effectiveness of sanctions and their collateral damages must rely on simultaneous consideration of the impacts of sanctions on different sectors and their trade-offs.
3. This study does not seek to determine which one of the parties to the sanction, i.e., the sanctioning states—sanctioner(s)—or the sanctioned state—sanctionee—is more liable for the environmental damages. Rather it argues that environmental damages have been unavoidable based on the current economic sanction practices and mechanisms.
4. This study does not investigate the human rights implications of the environmental impacts of economic sanctions while acknowledging that human rights and the environment are interlinked and noting the fact that enjoying human rights without access to a safe, clean, and healthy environment is impossible [46,47].
5. Iran's environmental problems, reviewed in this study, have not arisen overnight, but after decades of unsustainable management based on short-sighted development policies [31,48]. Regardless of sanctions, Iran would have had major environmental problems today even in the absence of sanctions under its current environmental governance schemes.
6. Economic sanctions have accelerated environmental degradation but must not be recognized as the main driver of the country's short-sighted development policies, lack of determination to address its environmental problems, and prioritization of ideological objectives over sustainable development. Accordingly, the findings of this study must not be used for apologetic interpretations of the wrong decisions made by the Iranian decision makers and their environmental outcomes over the last decades.
7. Iran sanctions have been evolving in terms of strength and scope. The impacts of sanctions accumulate and normally appear in the long run. The sanctioners and sanctionee, i.e., Iran, have been continuously revising their strategies for minimizing and maximizing the impacts of sanctions, respectively. Appreciating the evolving nature of the Iran sanctions problem and understanding the dynamics of the economic sanction enforcement-response games are necessary when interpreting the study findings. The analysis cannot determine how changes in sanction schemes, responses

to sanctions, circumstances, or courses of actions in the past could have changed the status of the environment and the effectiveness of sanctions.

8. Equating statistical correlations to causations in exploring the impacts of Iran sanctions can lead to very misleading conclusions. For example, an increase in the number polluted days in Tehran in a particular year cannot necessarily be attributed to the presence or absence of sanctions, as the number of polluted days can depend on other variables such as wind, precipitation, and temperature changes during the year. To be able to properly explain observations and identify the underlying causal mechanisms of the problem, one must be familiar with the historical and technical context, as well as the involved complexities.

Readers are referred to Madani [1] for additional precautionary notes regarding the study of the environmental implications of economic sanctions as a problem that belongs to the class of complex, coupled human–nature systems [49–51] with multiple interacting and evolving subsystems, drivers, and variables.

3. State of the Environment in Iran: Did Sanctions Cause Iran's Environmental Problems?

Iran is currently dealing with a diverse range of environmental challenges. Water bankruptcy [33] is the most recognized environmental problem of the country. Rapid population growth and improper spatial distribution of the population, economically inefficient and environmentally unsustainable agricultural growth, and mismanagement of the water are the major drivers of the country's significant water problems, worsened by climatic variability and change [31,52].

Agriculture withdraws more than 90% of Iran's water. Despite declining water availability and frequent droughts, Iran's agricultural area and production has continued to grow [53]. This growth, which was greatly motivated by the food self-sufficiency agenda to minimize Iran's reliance on the international market to satisfy its food demand, would have been infeasible without the unsustainable use of the country's water resources [53,54]. The total water use exceeds the total renewable surface and ground water budget of the country. Non-renewable groundwater is being tapped [55–58] and surface water is stored behind large dams and diverted through inter-basin water infrastructure systems [59–61] to satisfy the growing water demand. Draining aquifers have led to declining groundwater levels [62,63] and excessive surface water use has significantly reduced river flows (e.g., Zayandeh-Rud, Karun, Dez, Karkheh, Kor, Qezelozan, and Sefidrud), subsequently drying up wetlands.

Lake Urmia, once one of the world's largest hypersaline lakes, has significantly shrunk, mainly due to the anthropogenic impacts of development in north-western Iran [64]. Excessive dam building, water diversion, and increased water use for agricultural expansion together with frequent droughts [65–69] led to the drying of Iran's largest wetland that had been declared a Wetland of International Importance by the Ramsar Convention in 1971 and designated a UNESCO Biosphere Reserve in 1976. The Lake Urmia shrinkage tragedy is among the major symbols of environmental degradation in Iran, but its story is not unique. Other major wetlands around the country such as Anzali, Shadegan, Bakhtegan, Jazmourian, Hoor Al-Azim, Hamoun, Gavkhouni, and Parishan have also shrunk due to reduced water inflows.

The water challenges of the country are not limited to water quantity problems. Declining water availability in addition to the increasing biological and chemical pollution from agricultural, industrial, medical, and domestic effluent and waste have resulted in water quality degradation in underground and surface water resources [33,70–74]. This has made water unsuitable for various uses in some parts of the country [75–77]. The Caspian Sea in the north and the Persian Gulf and Sea of Oman in the south are exposed to high levels of pollution from river discharges and human activities in the coastal zones of Iran and its neighboring countries [78–84].

Deforestation is on the rise [85–87] due to ineffective forest protection, reduced water availability, frequent droughts, overcutting trees and illegal logging, wildfires, urbanization,

and the conversion of forests into agricultural and industrial sites. Deforestation, land use changes, reduced soil moisture, over-grazing, over-plowing, over-cropping, and poor land management practices have increased soil erosion, wildfires, flood damages, landslides, and desertification.

In 2008, Iran had the highest average density of domestic sheep of any arid rangeland country in the world and the fifth largest sheep population in the world, with about 52 million animals [21]. At the time, the livestock population was believed to be more than twice the sustainable carrying capacity of the country's rangelands. The livestock population was more than five times bigger than the carrying capacity of the Ilam Province's rangelands in 2008 [32]. Over-grazing is a major threat to protected areas, especially to those located in arid and sub-arid rangelands [21]. Deforestation, agricultural activities, water and waste pollution, the excessive use of fertilizers [53], and pesticides have impacted soil quality across the country [88–90], limiting its land suitability for agriculture [91].

Dried wetlands, abandoned farms, land use changes, deforestation, soil erosion, and desertification have led to frequent dust and salt storms, threatening people's health [28], causing significant damages to the ecosystem, reducing agricultural productivity, and increasing soil loss and the removal of valuable organic matter and soil nutrients [92]. The declining levels of water in the aquifers due to the over-abstraction of groundwater [62,93] have resulted in increasing land subsidence and the emergence of sinkholes in different parts of the country [37,94–99], threatening critical infrastructure.

Air quality degradation is a major problem in Iran's major cities. Rapid and unchecked urbanization, high population density, the inefficient use of non-renewable energies and low-quality fuels, the growing and aging fleet of gasoline and diesel vehicles, limited public transportation capacity, and proximity to active industrial zones are among the typical causes of air pollution in Iran's metropolitan areas [100–103]. Tehran, Iran's capital and most populated city, is among the world's top polluted megacities in terms of ambient PM10 levels [104].

Frequent dust storms are the cause of air pollution in some other parts of the country such as the Sistan and Baluchestan Province [105–108], Iran's second largest province by area in the southeast, bordering Afghanistan and Pakistan, the Khuzestan Province [109–111], in the southwest of the country, bordering Iraq, as well as other provinces in the west such as Kermanshah, Kohgiluyeh and Boyer-Ahmad, and Kurdistan (Kordestan). These areas are exposed to the dust originating in Iran's neighboring countries as well as the local dust sources produced as the result of drying wetlands, reduced soil moisture, deforestation, soil erosion, and desertification. In 2016, Zabol, a city bordering Afghanistan in the Sistan and Baluchestan Province, was the world's most polluted city in the World Health Organization (WHO) database in terms of PM2.5 levels [112,113]. In 2011, the WHO database had four Iranian cities in the top ten most polluted cities of the world in terms of PM10 levels. At the time, Ahvaz (Ahwaz), the capital of Khuzestan Province, was the world's most polluted city in the world, followed by Sanandaj, the capital of Kurdistan Province, as third, Kermanshah, the capital of Kermanshah Province, as sixth, and Yasouj, the capital of Kohgiluyeh and Boyer-Ahmad Province, as ninth [114–116].

Air pollution in Iran is a major threat to public health [28,117–119] and has major economic, social, justice, and even security implications. Air quality degradation reduces agricultural productivity and causes major damages to the ecosystem [120], infrastructure, and cultural/historic and natural heritage sites. In Tehran alone, the economic damage of the morbidity and mortality associated with Tehran's air pollution is estimated at 2.6 billion USD per year [104]. This value excludes the economic cost of reduced agricultural productivity, ecosystem service losses, infrastructure damages, quality of life and visibility degradation, education days lost by children and university students due to school closure (closing schools, universities, and even government offices is a strategy used by the government during days of extreme air pollution), and some other major indirect costs of air pollution.

Managing solid waste, including municipal [121], industrial and hazardous [122,123], agricultural, and bio-medical waste [124,125], is another growing but overlooked environmental challenge in Iran. Iran's average per capita municipal solid waste production of 745 g per day, equivalent to 272 kg per person on an annual basis [121], is much smaller than the daily municipal solid waste generation per capita in many countries in the developed world such as the United States (2.58 kg), Canada (2.33 kg), Australia (2.23 kg), Germany (2.11 kg), and France (1.92 kg) [126]. Yet, this amount cannot be properly handled due to the lack of infrastructure, planning, and investment in the waste sector. While the country collects 90% of its municipal solid waste [121], it ends up sending most of it directly to landfills without any recycling due to the lack of the required system for waste segregation at source. Landfill leachate is a major threat to surface and ground water, soil, and the ecosystem. Plastic pollution is on the rise in the absence of recycling infrastructure and regulatory and incentive systems that can promote plastic use reduction and recycling. Other factors and drivers that have turned waste into one of the most pressing environmental challenges of Iran include but are not limited to: population growth; increased consumerism and production; unsustainable manufacturing and food production; inadequate landfill capacity and improper selection of landfill sites; the lack of sufficient waste collection, processing, management, and recycling infrastructure; the absence of effective waste management regulations and institutions; ineffective cooperation among the responsible authorities; and the lack of systematic efforts and regulatory and financial frameworks to promote waste production reduction and recycling.

These environmental problems constitute a serious threat to Iran's ecosystem health. The ecosystem of Iran contain 197 mammal species, 8000 plant species, 227 reptile species, 535 bird species, 21 amphibian species, 160 freshwater fish species, and 710 marine fish species [127]. Iran has 30 national parks, 170 protected areas, 45 wildlife refuges, and 37 national natural heritage sites, covering nearly 11% of Iran's area and protected by Iran's Department of Environment. The financial, equipment, staff (specifically, a sufficient number of competent ranger patrols), and logistic restrictions of the Department of Environment limit its capacity to properly protect these areas and the ecosystem that relies on them. The overviewed environmental problems of Iran together with some anthropogenic activities that directly harm Iran's flora and fauna (e.g., road construction and road accidents involving animals, human-induced fire events, mining and industrial activities, logging and poaching, and over-grazing) have caused major biodiversity losses in Iran over the past decades. Almost 100 species of vertebrate fauna in Iran are currently considered vulnerable or endangered according to the International Union for the Conservation of Nature (IUCN) Red List [21].

Iran's environmental problems have been exacerbated by climatic variability and change and extreme events. Extreme climate events such as droughts and floods have been common and costly to Iran [33,52]. Frequent, long, and intense droughts in Iran in the past four decades have reduced water availability and the yield of rainfed agriculture, dried up wetlands, and increased groundwater use, desertification, and ecosystem damages. On the other hand, floods, especially flash floods, during the same period were destructive and associated with casualties. There is no agreement among scholars (with a reasonable certainty) on the level of the historical impacts of climate change [33]. Nevertheless, most future projections portray warmer and drier conditions for Iran, which could further increase water shortage [128–130] and ecological damages that could reduce agricultural productivity. Moreover, climate change is expected to increase the frequency and intensity of extreme events such as floods, droughts, heat waves, and wildfires. The ongoing environmental degradation in Iran also makes its people and ecosystem more vulnerable to future extreme events. The widespread, costly, and extreme flood events of Nowruz 2019 in Iran, which were unprecedented in the last decades, were a wakeup call about the high variability of climate norms, the possible consequences of climate change [131], and the high vulnerability of a nation that has significantly manipulated its ecosystem.

The sustained degradation of Iran's environmental conditions is reflective of its unsustainable development. Efforts and plans to develop the country without sufficient attention to their environmental impacts are now causing major national security threats. Water shortage is affecting agricultural production, creating food insecurity risks. Unemployment, caused by environmental degradation (e.g., farmers and fishers losing jobs), and poor living and public health conditions in certain areas (e.g., rural and urban areas exposed to dust storms), can potentially promote migration, settlements in suburbs, and economic inequality, subsequently leading to social instability, tensions, protests, and national security problems. Regardless of the impacts of sanctions, Iran's environmental problems cannot be addressed without major reforms in its environmental governance institutions, management structure, and development plans.

Evidently, Iran's environmental problems, reviewed above, did not arise overnight, but after decades of unsustainable management based on short-sighted development policies [31,39]. Therefore, recognizing sanctions as the root cause, as done by some Iranian officials, is not justified. Just as with climate change, sanctions are not the driver or cause of Iran's current environmental problems. However, one can still investigate if, similar to climate change, sanctions have amplified Iran's environmental degradation in any way. Instead of focusing on statistical correlations and numbers, the analysis focuses on uncovering the underlying mechanisms that can explain why and how international economic sanctions have impacted and continue to impact Iran's environment. This will be supported by providing various examples that suggest that Iran's environment has been an inevitable victim of the economic sanction enforcement-response game.

4. The Environmental Impacts of Sanctions

Although sanctions have not caused Iran's environmental problems, they have impacted its environment in three general ways: (1) restricting its access to technology, service, and know-how; (2) blocking international aid for the environment; and (3) increasing the natural resource intensity of Iran's economy.

4.1. Restricting Access to Technology, Service, and Know-How

The success of economic sanctions in impacting Iran's banking system and financial transactions is undeniable. Sanctions have been effective in restricting the flow of money in and out of the country via official and sanction-free banking channels, limiting Iran's access to its export income and its assets abroad and devaluating Iran's currency. These outcomes reduce Iran's ability to purchase goods, technology, knowledge, and services (GTKS) in the international market, increasing the cost of foreign GTKS when they are acquired through unofficial channels and sanctions-busting. The resulting increased cost further reduces Iran's interest in foreign GTKS and diminishes its potential capacity to gain access to GTKS in sectors that it considers non-essential or non-urgent, such as the environmental sector. (Although, the environment is an urgent subject from the technical and sustainable development standpoints, in practice, it has been treated as a non-urgent matter from the public policy standpoint. Readers are referred to Section 4.3 and Madani [132] for further information on this argument.)

Iran's market has lost its appeal to the international GTKS vendors under sanctions. Providing GTKS and doing financial transactions with Iran can be followed by major punishments and financial penalties. International GTKS vendors and financial institutions are reluctant to have associations with Iranian business due to the high risk of losses under sanctions. This risk, in addition to the practical complexities and cost associated with getting the required US Treasury Department licenses for business with Iran and the difficulties in exporting sanctions-exempt goods to and receiving money from Iran through official banking channels, has made vendors and financial institutions over-conservative. As a result, business with Iran is avoided even when there is no violation of sanctions, restricting Iran's ability to acquire the GTKS, which are already exempt from or can be exempted from sanctions. (The international media, Iranian officials, and scientific

literature have repeatedly claimed that the US sanctions have hampered Iran's ability to import medicine, medical equipment, and food [15,133–136], even though "the sale of food, medicine, or medical devices to Iran" is exempt from the US economic sanctions on Iran [137,138] under a "general license" [139]).

Economic sanctions lower the international interest in financial investments in Iran's various economic sectors, slowing down the technologic and scientific progress, innovation, and efficiency improvements in sectors such as energy, water, food/agriculture, mining, production, and service that could potentially reduce the ecological footprint of Iran's development and benefit its environment. For example, the re-imposition of sanctions in 2018 reduced the international interest in investing in Iran's energy market. Quercus, a British renewable energy investor, was one of the companies that ceased all of its activities in Iran, including its plan to construct a 500-million Euro solar power plant with a capacity of 600 MW [140].

In the absence of economically competitive foreign GTKS, the sanctionee (Iran) has two options:

1. Completely disregarding its need to acquire specific GTKS
   For example, the South Pars refineries use a specific type of absorbent for mercury removal from natural gas. The manufacturers of this type of absorbent, such as Johnson Matthey (JM) and Axens, have refused to sell it to Iran. As a result, mercury is not being properly removed from natural gas, damaging the environment (with major public health implications) both at the production point (refineries) as well as the consumption points (houses, offices, schools, hospitals, factories, etc., (indoor and outdoor)).
   In some industries, the companies that have sold equipment to Iran in the past are reluctant to provide spare parts and the needed service (repair, operation, inspection, and maintenance). Many companies that had long-term contracts for providing various technical services (e.g., software updates, operation optimization, new knowledge delivery, training, instrumentation, and inspection) have suspended their contracts and stopped their service under sanctions without any penalty to their service buyers. These issues have resulted in Iran's restricted access to the best available technology and know-how, subsequently reducing the resource use efficiency and increasing the ecological footprints of different sectors in the country.
   Numerous examples of this kind have occurred in the vehicle manufacturing and transportation industry with major environmental implications in terms of emissions. Major Iranian car manufacturers have continuously postponed of the adoption of the Euro 5 emission standard while blaming sanctions as the cause of their limited access to required technologies. In 2018, the Construction and Transportation Commission of the Tehran's City Council suspended the budget for installing diesel particulate filters (DPFs) on the 700 old buses (defined as buses that are more than 8 years old) used by the Tehran Bus Company (a subsidiary of Tehran Municipality, which is overseen by the Islamic City Council of Tehran) for public transport. (More than half of about 6000 buses used by the Tehran Bus Company run on diesel. The average age of the company's bus fleet is 11 years old. More than half of the buses belong to the "old" category. By 2023, almost 90% the company's bus fleet will be "old" if there is no fleet retrofit). In 2019, upon the request of Iran Khodro Company (one of the major vehicle manufacturers in Iran and the Middle East), Senior Vice President Eshaq Jahangiri ordered the Minister of Industry, Mines, and Business and the Head of Iran's Department of Environment to waive the requirement for installing diesel particulate filters on diesel trucks under the sanctions (Figure 1). These decisions, made under the economic sanctions, have a direct impact on the level of air pollution with significant socio-economic, health, and environmental implications.
   In addition to the limited and costly access to DPFs under sanctions, it has been argued that the diesel produced in Iran does not meet the required quality standards, making DPFs dysfunctional and redundant. This argument has been rejected by Iran's

Department of Environment. Nevertheless, even if the argument is valid, sanctions have been introduced as the major obstacle to improving the quality of the fuels produced in Iran. Therefore, regardless of the validity of the claim, one can conclude that the economic sanctions have directly impacted air quality in Tehran (as a catalyst that has intensified air pollution).

2. Settling for cheaper but lower quality (e.g., used, outdated/not state-of-the art, and not meeting environmental quality standards) GTKS provided by foreign or domestic suppliers

For example, after the re-imposition of US sanctions in 2018, Siemens refused to ship the syngas compressors it had produced for the Zanjan Fertilizer Project (ZFP) under an old purchase agreement in fear of targeted retaliation from the US. Indeed, Siemens did not risk losing its 20 billion USD a year revenue (about 20% of its global sales) in the United States where it employs about 50,000 workers [141] to make a very small revenue in Iran (similarly, many other companies with a strong presence in the US have refused to do business with Iran, in fear of losing their share from the US market). ZFP ended up purchasing Chinese compressors with lower environmental standards, leading to higher emissions.

Similar stories have occurred in Iran's methanol industry. Iran has the potential to become one of the leading producers of methanol. Yet, its access to state-of-the-art technologies has been cut by the sanctions. JM and Haldor Topsoe have refused to provide autothermal reforming technology (ATR) to the Eslamabad-e Gharb refinery in Iran. Thus, Iran is in the process of launching this refinery using older technologies, leading to higher water use and carbon footprints (in 2020, Iran's neighbor, Turkmenistan, successfully operationalized the world's largest ATR-based methanol plant with the help of Haldor Topsoe [142]). In another methanol project in south Iran, the international licensor of the project, Haldor Topsoe, did not respect its contractual obligations after the re-imposition of sanctions and refused to deliver three critical equipment parts. These parts were subsequently replaced by their Iranian alternatives that did not meet the environmental standards specified in the Process Design Package (PDP) and approved by the original licensor.

In 2006, INPEX Corporation, Japan's largest oil and gas exploration and production company, pulled out of the oil extraction project in the Iranian part of Hoor Al-Azim, a major transboundary wetland in southwestern Iran, overlying large oil fields. The implementation of the project was pursued and completed by Chinese and Iranian companies. Yet, the original design specifications that were suitable for oil drilling in wetlands (wet environments) were not pursued. The implemented project and installed oil rig and equipment that are in operation today are suitable for dry environments. As a result, not only was the wetland area kept dry during the implementation of the project, but also releasing large volumes of water into some parts of this highly manipulated wetland (both Iran and Iraq have substantially modified the natural conditions of the Hoor Al-Azim wetland by installing a series of dikes, culvers, and roads) has become prohibitive given the damages it can cause to the installed equipment. The drying up of Hoor Al-Azim reduced the implementation cost of the project under sanctions, but in the long run, it has caused significant ecosystem damage and turned the wetland into a major dust source in the region, affecting the lives and health of people in the Khuzestan Province during long episodes of dust storms that have been unprecedented in the region.

In 2010, when the economic sanctions on Iran's gasoline imports were signed into law, Iran was importing 40% of its gasoline. President Barack Obama had projected that penalizing Iran's gasoline suppliers and increasing pressure on the international banking system to stop working with Iran would make it harder for the country to buy refined petroleum and the required goods and services to modernize its oil and gas sector, the backbone of its economy [143]. This projection was somewhat correct. Iran's petrol imports dropped by 75% [17], but Iran immediately responded

to the new sanctions by increasing its local refining capacity, producing lethal, but cheap, petroleum that could run vehicle engines but was highly destructive to the environment. Iran's locally produced petroleum at the time contained 10 times the level of contaminants compared to imported fuel and the sulfur level in diesel gas sold in Tehran was 8000 parts per million (ppm) [144,145], 800 times greater than the US Environmental Protection Agency (EPA) standard. Similar to the other examples above, Iran tried to withstand the sanctions' pressure on the oil and natural gas sectors by making choices that had major costs for the environment but could help the country survive in the short run.

In some cases, relying on domestic GTKS delivery is not necessarily more economically effective for the sanctionee, but it can help reduce the national insecurity risks. For example, while domestic wheat production can be costlier than importing wheat, the fear of sanctioned food access and national security problems might justify the continuation of conventional and inefficient domestic food production for the country leaders. Given the tensions and international conflicts that Iran has experienced since the 1979 Islamic Revolution, food security has been a significant public policy agenda for the country's leaders. The experiences of other under sanction countries and observing their vulnerability to food import reductions have turned food insecurity into a major phobia. As a result, Iran has seriously pursued the ambitious goal of self-sufficiency in food production [31,33]. This policy has had major negative impacts on the country's water and environment. Despite these impacts, the country leaders consider this policy a necessity given their national security concerns that drastically intensified under sanctions and extreme international pressure. (Creating job opportunities has been another motivator for expanding the agricultural sector. The dependency of a significant portion of the country's population on the agricultural sector for their jobs [31] creates another national security concern as reducing the size of this sector could cause unemployment for the weaker economic groups of the society). Although food export to Iran is supposedly free of sanctions and importing at least part of the needed food can decrease the economic and environmental costs of food production for Iran, the country sees food-dependency as a major vulnerability that can be targeted by its enemies and by sanctions. Similarly, sanctions have promoted self-sufficiency and minimal international dependency policies in other sectors (e.g., car manufacturing, gasoline, and pharmaceuticals) despite their long-term environmental costs for the country.

In all cases, the long-term environmental considerations have been overlooked in favor of matters that are considered more urgent by the government (e.g., addressing national security issues, creating new jobs, and increasing revenues). Evidently, Iran's environment can take a major hit both when GTKS are required specifically for the environmental sector (e.g., air quality monitoring equipment, environmental instruments, environmental/energy software, and training) and when the GTKS are not required specifically for the environmental sector but have considerable positive environmental benefits (e.g., hybrid cars, new passenger aircrafts with better fuel use efficiency, improved petrochemical technologies, or cement production technologies with reduced carbon and water footprints).

Environmental research and education have also been impacted by the economic sanctions. As in other cases, impediments to the transfer of research and training funds and financial interactions with Iran [146] have been the major causes of this impact. Public universities and research institutes in Iran are considered as government institutions and their staff are government employees; therefore, in theory, financial interactions with them and knowledge transfer to them can violate the sanctions rules. Potential penalties of interacting with Iranian universities, therefore, as well as with citizens, unclarity about what can constitute a transfer of knowledge that violates sanctions [147,148], currency collapse [149], limited access to equipment, instruments, software, and know-how, decreased travel of international researchers to Iran under sanctions and after enforcing the Visa Waiver Program Improvement and Terrorist Travel Prevention Act of 2015 (according to

this Act, which became law in 2016, the citizens of 38 countries, who could previously travel to the US without a visa under the Visa Waiver Program (VWP), now have to obtain a visa for travel to the United States if they have visited or been present in Iraq, Syria, Iran, Sudan, Libya, Somalia, or Yemen after 1 March 2011), and more restricted access to training and capacity building programs (Figure 2) are among the other impacts of sanctions on environmental research and education. All these impacts and restrictions limit Iran's knowledge, innovation, technologic and scientific advancements, education, and capacity building in the environmental sector, which are essential to address the country's crippling environmental problems.

دفتر معاون اول
رئیس

بسمه تعالی

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جناب آقای رحمانی
وزیر محترم صنعت، معدن و تجارت
جناب آقای دکتر کلانتری
معاون محترم رییس جمهور و رییس سازمان حفاظت محیط زیست

با عرض احترام

نامه شماره ص‌خ/۹۸۴۰۱۰۱۶/دب مورخ ۹۸/۶/۱۷ شرکت ایران خودرو دیزل (تصویر پیوست) درخصوص «**درخواست موافقت با پیشنهاد حذف الزام نصب فیلتر جذب ذرات معلق(DPF) در خودروهای دیزلی تا زمان رفع تحریم‌های ظالمانه و تضمین سوخت با کیفیت مناسب**»، به استحضار جناب آقای دکتر جهانگیری معاون اول محترم رییس‌جمهور رسید، پی‌نوشت فرمودند:

«جنابان آقایان رحمانی و کلانتری
با توجه به شرایط تحریم و نیاز کشور به کامیون‌های مذکور، با نظر مساعد
بررسی و برای مدتی مجوز صادر شود.»

کاظم چهره گشا

Figure 1. A letter (in Persian) to Reza Rahmani, Minister of Industry, Mines, and Business, and Issa Kalantari, Vice President and Head of Department of Environment, from Kazem Chehehgosha, Iran's Senior Vice President's Chief of Staff, signed on 11 September 2019. In this official letter, Chehrehgosha informs Rahmani and Kalantari of the order by the Senior Vice President, Eshaq Jahangiri, regarding the request by Iran Khodro Company (IKCO), a major Iranian vehicle manufacturer, that requested a waiver of the requirement for installing DPFs (diesel particulate filters) on diesel vehicles until the "oppressive sanctions" are lifted and proper quality fuel production is assured. In this order, Jahangiri instructed Rahmani and Kalantari to evaluate the IKCO's request with a "positive view" and grant permission "for some time", considering the "sanction conditions and the country's need for the referenced trucks (in the request)".

Figure 2. The message received by an Iran-based user when trying to register for the "Introduction to Sustainability" massive open online course (MOOC) on Coursera, an online education platform. Similar to other major online learning platforms such as EdX and Udacity, Coursera recognizes international sanctions and the US export control regulations as the main barriers to provide education service to users based in Iran.

4.2. Blocking Interntional Aid for the Environment

International environment-related aid has also been among the direct targets of sanctions on Iran, with obvious negative impacts (in terms of opportunity loss) on Iran's environment. International aid and development funds as well as cooperation with and receiving research/training support from intergovernmental agencies are not subject to sanctions. However, Iran's access to these options has become strictly limited under sanctions. The practical complexities that can arise during the implementation of aid projects because of sanctions, the major barriers to the transfer of funds to Iran through official banking systems, and the strong political influence of the United States as a major donor to intergovernmental organizations are among the major obstacles for Iran to benefit from the funds and services of intergovernmental and international organizations.

Since the 1992 Rio Earth Summit, the Global Environment Facility (GEF), established with the aim of helping tackle the planet's most pressing environmental problems, has funded many countries in crucial areas such as land degradation, biodiversity, chemicals and waste, international waters, sustainable forest management, and climate change. Iran has been one of the beneficiaries of GEF, having received nearly 31 million USD (this number is small compared to Iran's national income and its government's annual budget; but given the low budget allocations to the environmental sector and environmental activism in Iran, relatively small international environmental aid funds have been impactful) for 18 environmental projects [150] that were implemented through the collaboration of the Iranian government, companies, and non-profit organizations with intergovernmental agencies such as the UNDP (United Nations Development Programme), UNEP (United Nations Environment Programme), FAO (Food and Agriculture Organization of the United Nations), the World Bank, and UNIDO (United Nations Industrial Development Organization). GEF's financial support could have been much more, i.e., up to 52.67 million USD, in the absence of sanctions (Figure 3). GEF's funding to Iran was significantly reduced under the sanctions, starting with the fifth round of GEF funding. During this round (2010–2014), less than 15% (4.2 million USD) of the funding that had been originally allocated to Iran (28.77 million USD) was utilized. In round six (2014–2018), GEF allocated 17.21 million USD to Iran, which remained completely unused. GEF has allocated 10.89 million USD to Iran in the seventh round (2018–2022) with a 0% utilization rate to date.

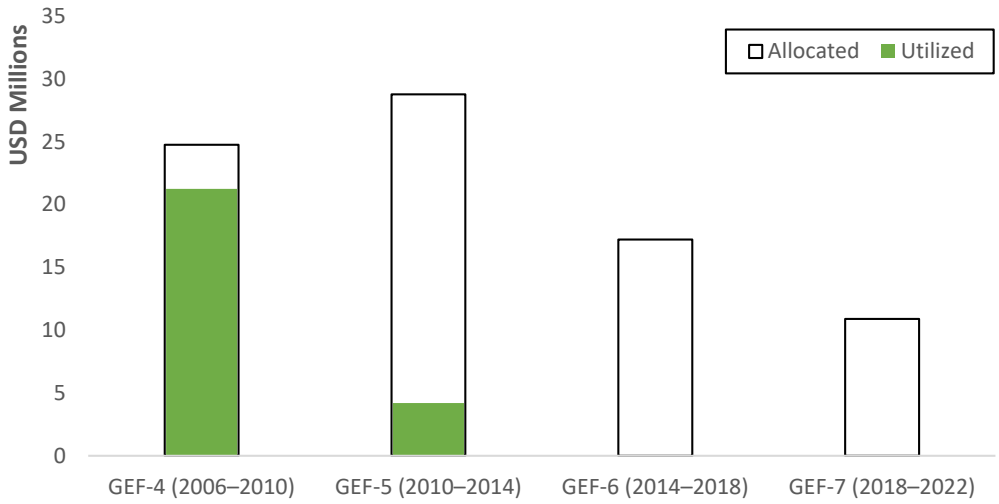

Figure 3. The support from the Global Environment Facility (GEF) for Iranian projects in the last four funding rounds. The gap between the allocated and utilized funding in the fourth round was due to the cancellation of projects, not driven by sanctions. In the other rounds, sanctions have limited Iran's access to the allocated funding.

The World Bank is an example of another intergovernmental agency whose support for Iran has been impacted by sanctions (Figure 4). The last Iranian project funded by the World Bank was closed in 2012. (Recently, the World Bank approved a 50 million USD COVID-19 emergency response project, which makes Iran one of the 100 developing countries that will receive COVID-19 emergency response funding from the World Bank; this project that has been funded "on an exceptional basis based on humanitarian needs" is supposed to be implemented by the WHO, which would receive the World Bank funding, i.e., there will be no funding flow to the government of Iran [151]. The last World Bank emergency response funding given to Iran from the World Bank was in 2004, following the 2003 Bam earthquake. This project, i.e., the Alborz Integrated Land and Water Management Project (with the World Bank funding commitment of 120 million USD), was approved for funding in 2005, along with another water-related project, i.e., the northern cities water supply and sanitation project (completed in 2010 with the World Bank funding commitment of 224 million USD). The final assessment reports of both projects refer to a range of procedural challenges that resulted from the UN sanctions and constituted an impediment to the smooth delivery of the projects, including a severely delayed release of funds from the World Bank, massive implementation delays, procurement disruptions and onerous procurement approval processes, difficulty in transfer of funds and dealing with the banking system, and travel restrictions [152,153].

CGIAR (Consultative Group for International Agricultural Research), a global research partnership of funders and international agricultural research centers for a food secure future, involved in poverty reduction, food and nutrition security enhancement, and natural resources improvement, is another intergovernmental organization whose contribution to environmental improvements in Iran have been impacted by economic sanctions. The International Maize and Wheat Improvement Center (CIMMYT), a CGIAR center (international non-profit research-for-development organization) with the mission of contributing to food security was in collaboration with Iran to upgrade its wheat system, helping the country with producing new varieties of seeds for its hot and cold climates [154]. Given Iran's food security initiatives and their direct water and environmental impacts, the country's environment would greatly benefit from improvements in the agricultural sector. Yet, following the re-imposition of US sanctions, only a few months after launching its conservational agriculture center in Khuzestan in a joint project with Iran, CIMMYT discontinued project support to Iran and closed its Iran office in Karaj on 1 November 2018. The organization cited "growing constraints on CIMMYT's operations in Iran as a result of

heightened sanctions" to justify its decision [155]. Two days later, on 3 November 2018, the International Center for Agriculture Research in the Dry Areas (ICARDA), another CGIAR member, closed its office in Tehran and announced the discontinuation of its project support to Iran, making a reference to the "growing constraints on ICARDA's operations in the Islamic Republic of Iran as a result of heightened U.S. sanctions" [156]. Not long before, in 2017, ICARDA, a non-profit agricultural research institute with the mission of reducing poverty and enhancing food, water, and nutritional security and environmental health in the face of global challenges, including climate change, had reported its collaboration with Iran and had decided to provide funds for a project that aimed to raise crop production in four water-scarce provinces of western Iran [157].

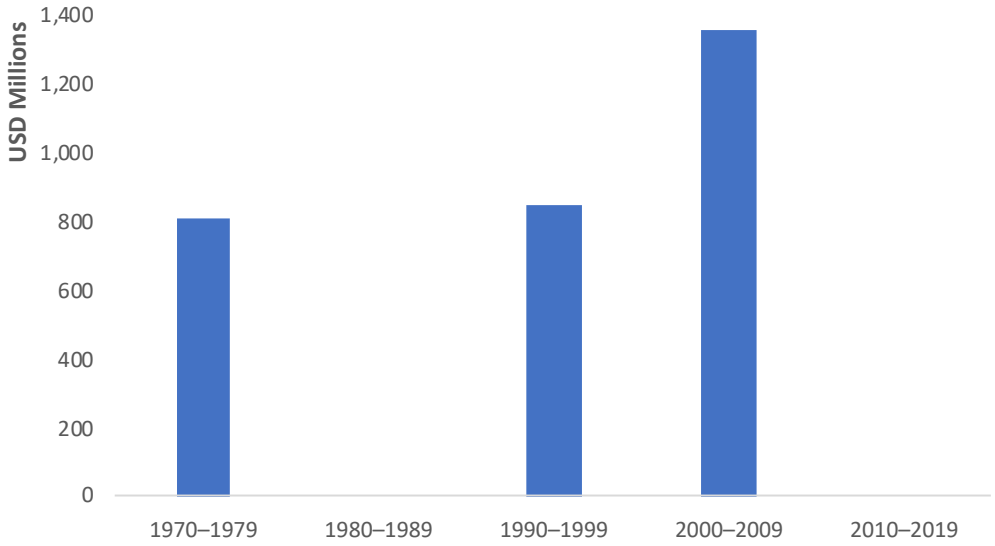

Figure 4. The World Bank's funding to Iran (1970–2019).

Sanctions have also impacted the operations of some intergovernmental bodies in Iran, mainly due to obstacles to transferring funds through the official banking system. Nevertheless, over the years, they have found solutions to overcome the financial challenges. Despite the sanctions-induced practical complexities, some intergovernmental bodies, whose work has major environmental implications and who are less under the political influence of the United States, such as WHO, FAO, UNEP, UNHCR (United Nations High Commissioner for Refugees), UNIDO, WFP (World Food Programme), and UNICEF, have continued to work with and support projects in Iran (except for UNICEF, none of the mentioned intergovernmental organizations has a head office in the United States). This has not been the case for many funding entities, regional donors, non-profit organizations, and governments that had an interest in supporting environmental projects in Iran but faced difficulties in transferring funds to Iran, even in the case of small projects. Additionally, the effort and time needed to receive a license from the Office of Foreign Assets Control (OFAC) of the US Department of the Treasury for supporting environmental projects in Iran (the "humanitarian exception" of US sanctions does not automatically apply to environmental aid; nonetheless, receiving an OFAC license to do and support environmental work in Iran has been possible in practice through lengthy processes) have served as a major demotivator for supporting Iran-related environmental projects. Even transferring natural disaster-related and emergency monetary aids and donations (e.g., transfer of cash aid and relief packages to Iran following the major floods in spring 2019 [158,159]) that are exempt from sanctions as humanitarian aid has proven difficult in practice given the barriers that have been developed in the international banking system by the sanctions.

4.3. Increasing the Natural Resource-Intensity of Iran's Economy

Sections 4.1 and 4.2 provided a series of examples that suggest that sanctions have effectively impacted Iran's environment. Limited access to knowledge, technology, goods and services, education and training, and international aid together with collapsed currency and money transfer obstacles in the banking systems under sanctions accelerate Iran's environmental degradation. Determined to continue its development and pursue the plans that have resulted in the enforcement of sanctions at the first place, Iran has loosened the environmental considerations/regulations and even violated its own constitution to minimize the impacts of sanctions on its development path. As a result, the country has been able to continue its structural developments by making huge sacrifices in the environmental sector with lasting and, in many cases, irreversible impacts. Yet, the main question to ask is why has Iran been willing to give up on its environmental needs in favor of its structural infrastructure (e.g., defense infrastructure)? In addition, one must ask why a country that has made research and technologic innovations in various sectors to reduce its international dependency under sanctions has not been successful in making similar progress in the environmental sector, where the required technology and even financial investments are significantly simpler and smaller? How does a country that makes ballistic missiles, launches satellites and space rockets, enriches uranium, becomes one of the top dam builders in the world [31], builds one of the world's tallest towers (Milad Tower), produces 97% of the medicine it needs [160], and makes much progress in different sectors under sanctions, fail so drastically in its environmental sector?

The answers to these questions lie in the causal dynamics that govern the overall behavior of the economy of a country under sanction in its pursuit of development, as illustrated by Madani [1]. These dynamics establish the third category of the environmental impacts of sanctions, i.e., increased natural resource-intensity of a sanctioned economy. These impacts are often more important as they amplify and normalize the other environmental impacts of sanctions and have lasting impacts. Madani [1] developed a generic causal model that illustrates the compound environmental impact of economic sanctions. This model uncovers the causal dynamics that establish an inverted-U-shaped relationship between economic development and environmental degradation that is similar to the well-known Environmental Kuznets Curve (EKC) [161–163], as shown in Figure 5. Economic sanctions function as major exogenous forces that pressure the economy and restrict economic growth. They act similarly to the economic recession but can be more impactful and paralyzing. A weakened economy loses its diversification capacity, faces increasing unemployment, and is challenged with import and technology acquisition problems. In this situation, increasing pressure on natural resources is a popular strategy to defeat degrowth, economic recession, income and production deficit, and rising unemployment. By boosting natural resource-dependent growth, a deteriorating economy can compensate for the production and import losses and decrease the unemployment level. This strategy periodically reduces the pressure on the economy while having long-term environmental consequences if the economy cannot get out of the degrowth and recession trap [1].

Sanctions can effectively constitute a major barrier to decoupling income from natural resources, making economic growth costlier to the environment. In response to sanctions on gasoline imports, Iran needed to produce its own gasoline. Limited access to international markets and its possible impact on food security encouraged Iran to pursue its unsustainable agricultural policies to minimize its international dependency. Low quality car manufacturing has been a strategy to cope with the impacts of economic sanctions on the automobile industry. The reduced income, increased costs of imports, and deficit for various goods are not the only justifications for Iran to respond in this way. Unemployment is a significant threat to national security. Therefore, Iran is also in desperate need of creating job opportunities. This need gives Iran strong motives to maintain and, if possible, even expand its economically and technologically inefficient natural resource-dependent sectors (e.g., oil and gas, petrochemical, agricultural, mining, car manufacturing, construction) that degrade the environment for the sake of job creation. This reflects the increased

role of natural resources in Iran's political economy and the effectiveness of sanctions in accelerating environmental degradation.

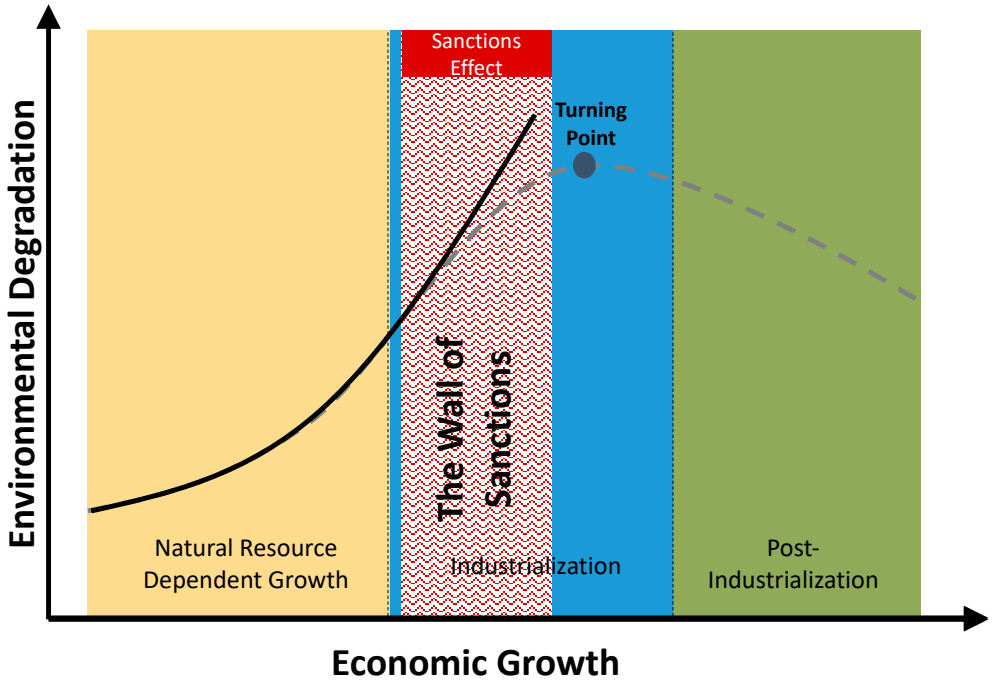

Figure 5. The relationship between economic growth and environmental degradation under sanctions [1]. The "Wall of Sanctions" functions as a barrier to changing the composition of the economy. The sanction effect increases the natural resource dependency of the economy and changes the shape of the EKC curve (Figure adapted from Madani [1]).

Sanctions can also reduce the relative urgency and importance of the environmental sector [132] for the policy makers in comparison to other issues such as employment, economic growth, defense, national security, food, energy, and housing [1]. A system that is operating in crisis management mode [31] has a very limited capacity to deal with problems that have a long-term nature, such as environmental problems. In this situation, problems that can cause immediate national security problems (e.g., shortage of essential goods or weapons) are prioritized over environmental degradation, thus explaining why Iran has been successful in launching a military satellite and building missiles but not in producing high quality cars, DPFs, and other technologies that are easier to develop and can benefit its environment. As discussed in Madani [1], under the sanctions' pressure, an ambitious state, like Iran, is willing to aggressively use its resources and compromise long-term national benefits in favor of its ideologic goals which are considered "abnormal" by the sanctioning states. The international political and economic pressure on Iran after the Islamic Revolution of 1979 has effectively increased its "thirst for development" [31] and its desire to build engineering infrastructure that can be presented as symbols of development (e.g., Milad Tower, concrete dams, and refineries). This unsustainable and survivalist strategy can earn pride, periodically boost the economy and create jobs, and ease the pressure of sanctions in the short run, but has major long-term environmental implications [17,31].

A state that fights for survival under the international sanctions can also change its attitude toward international environmental cooperation and environmental activism. Iran is a signatory to the Paris climate change accord but has never ratified it under the conflicts caused by domestic politics. It is hard to tell if Iran would have ratified the Paris Agreement if the sanctions had not been reimposed by the United States. but under the current situation, ratification of this agreement in the near future seems very unlikely. In the research and knowledge production space, the change of attitude towards

international cooperation and reduced international interactions can also result in reduced transparency and more limited access to information. Iran has also increasingly securitized its environmental space and jailed some environmental experts, fearing that environmental problems could turn into an effective cause to unite political opposition groups and turn into a significant national security threat [164,165].

5. Conclusions

Iran is suffering from a range of environmental problems, rooted in decades of unsustainable development, lack of foresight, and bad environmental governance. The problems will be intensified in the future unless serious policy reforms are implemented, and immediate actions are taken. Yet, the current environmental governance structure and the state of the country's political economy leaves minimal hope for seeing a meaningful change in the current environmental degradation trends.

This study explored if economic sanctions have played a role in Iran's environmental degradation process. Sanctions have not caused Iran's environmental problems, but they have catalyzed its environmental degradation. The impacts of sanctions on the international banking system, Iran's economy, and trades with Iran have effectively limited Iran's access to technology, know-how, service, and environmental aid, which has major implications for Iran's environment. Sanctions have effectively limited Iran's economic growth and its ability to decouple its economy from natural resources, thereby growing the role of natural resources in Iran's political economy and making economic production much costlier to the environment.

The observations reported in this paper are in line with the expected trends and drivers of accelerated environmental degradation based on the dynamic mechanisms described by Madani [1]. Although the reported observations belong to Iran, one can expect to see similar trends in other countries with comparable socio-economic and political conditions that are under the pressure of sanctions. It is noteworthy that in addition to economic sanctions, other drivers and circumstances that can weaken a state's economy such as corruption, economic recession, natural disasters, national/international crises (e.g., the 2007–2008 financial crisis or the coronavirus (COVID-19) pandemic), and wars can lead to accelerated environmental degradation.

This study did not evaluate if sanctions were effective or ineffective in reaching their goals, and if sanctions must be lifted or strengthened, nor whether those imposing sanctions on Iran must be blamed for the environmental impacts of sanctions. Instead, the study argued that Iran's environmental sector has been an unintended victim of the pressure imposed by the sanctions and the strategies adopted by Iran to reduce their pressure. This has major human rights, health, and justice implications for which both the sanctioning and sanctioned states must be held accountable [1].

Environmental problems are transboundary and their impacts cross political and geographical borders [1]. Iran's environmental problems have implications for its neighbors, the Middle East region, and the whole planet [17]. Given their significance, these problems have already affected Iran's international relationship with its neighbors such as Iraq, Turkey, and Afghanistan and can threaten regional stability in the long run, even after lifting the economic sanctions. Environmental problems are also transgenerational and take a long time to address [1,17]. The environmental problems of Iran, intensified by sanctions, cannot be fixed immediately after the sanctions are lifted. The lasting impacts of these problems will affect the future generations in Iran and the rest of the region.

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