The Plastic Waste Problem: Unveiling the Economic Factors Behind Singapore's Plastic Waste Exports

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Abstract

Singapore's plastic waste exports consistently declined since 2013, but suddenly stagnated after 2020. By considering the local and global context surrounding 2020-2022, this study illuminates some economic factors behind this plateau in Singapore's waste exports. Demand decreased because global attitudes increasingly discouraged the waste trade and the price of a major substitute for recycled waste plummeted. Costs of production from regulations and freight costs pushed down the supply of plastic waste exports but were outweighed by the sharp hike in plastic waste generation in Singapore caused by the impact of COVID-19 lockdowns on Singaporean consumer behavior. Meanwhile, importing countries' reliance on the plastic waste trade and Singapore's limited recycling capacity make it difficult for the quantity of Singapore's plastic waste exports to change. This study illustrates the situation with a microeconomic model, but maintains that further investigation is essential to formulate practical solutions.

Introduction

Plastic pollution is one of the biggest environmental challenges facing the modern world. Recycling allows us to repurpose plastic waste instead of allowing it to contaminate its surroundings. However, many countries that produce significant amounts of plastic waste, especially wealthy Western countries, are unable to process it on their own, hence exporting it to be processed in other countries (The United Nations Office on Drugs and Crime [UNODC], 2023). Before 2018, China received most of this waste. After China's waste import ban, developing countries especially in and near Southeast Asia became the next major destination of plastic waste exports. The plastic waste trade is a heavily flawed market contributing to devastating hazards in importing countries. Therefore, improving or minimizing the plastic waste trade is increasingly urgent.

Singapore has a unique socioeconomic and geopolitical context. Despite being part of the Association of Southeast Asian Nations (ASEAN), Singapore is more developed than most of Southeast Asia and often behaves like a more economically developed Western country. This behavior includes exporting lots of plastic waste to other ASEAN countries, especially Malaysia, Indonesia, and Vietnam, contributing to problems caused by the plastic waste trade in these countries (inferred from several datasets from the World Trade Organisation) (n.d., World Integrated Trade Solution [WITS]). Additionally, Singapore has extremely limited land, which poses a major challenge for building appropriate waste management facilities. As a Singaporean, Singapore's attempts to manage its waste while having to compensate for its tiny surface area are very intriguing.

Starting from a peak in 2013, Singapore's plastic waste exports steeply declined almost every year (Ritchie, 2022). However, starting from 2020, plastic waste exports suddenly stagnated, only slightly decreasing in 2021 and rising back up in 2022 to be nearly identical to 2020 numbers. By investigating the factors behind Singapore's plastic waste exports stagnating for this period, we may identify what obstacles and sudden changes impact Singapore's plastic

waste trade. This research would therefore better inform solutions to improve Singapore's plastic waste export situation, and by extension shed light on actions other countries should take too.

Literature review

This study aims to fill a gap in the existing literature by providing waste trade research where Singapore is the sole focus.

Analytical studies tend to observe general trends and events of the effects resulting from ASEAN's plastic waste trade with Western countries, especially the United States of America (USA) and the European Union (EU). ASEAN countries' poor waste management, including waste contamination and lack of suitable technology, exacerbates the negative impacts of waste imports (Liang et al., 2021). There have been reports on the negative impacts of plastic waste from overseas on importing countries. For example, a study conducted in Indonesia identified health risks from increased incidents of harmful substances in areas surrounding a tofu factory that burns plastic waste – both imported and local – for fuel (Petrlik et al., 2019). Studies also investigate microplastic contamination in water bodies in Southeast Asia, partially attributable to waste trade (Ng et al., 2023). Due to the aforementioned health and environmental danger, as well as more economically developed countries' supposedly higher quality plastic scrap often turning out to be contaminated, studies reflect ASEAN's decreasing demand for plastic waste imports (Galaiduk et al., 2020).

Singapore-specific research typically focuses on local waste management rather than waste trade. Some studies suggest ways to optimize plastic recycling (Lee & S. Wong, 2023); others look into waste collection and management systems as a whole (C. Wong et al., 2021). Overall, there is a lack of independent analysis of Singapore's plastic waste trade. Studies about plastic waste trade analyze Singapore alongside other countries, and studies about Singapore focus more on local waste management than Singapore's waste trade situation.

As highlighted in the introduction, Singapore has a very unique economic and geopolitical context. While comparative studies are important, it is also crucial to consider Singapore's situation independently to gain a comprehensive understanding. Thus, this study aims to synthesize findings on ASEAN plastic waste import trends and Singapore's local plastic waste developments.

Methodology

Because primary data is difficult to collect firsthand, this study uses data from datasets such as the World Bank and Our World in Data. As mentioned in the literature review, there are few existing research papers on Singapore's waste exports. This study will utilize news sources with thorough coverage on Singapore like Channel News Asia and the Straits Times. Such news articles will be corroborated with reports from The National Environment Agency (NEA), the United Nations (UN), and non-profit organizations to identify impacts that environment- or COVID-related waste trade trends in Southeast Asia may have on Singapore. News articles, government reports, and scholarly articles will be used for information on Singapore's current

waste management systems and domestic waste trends, from which the impacts on plastic waste exports can be inferred. The possibility of unidentified factors influencing trends poses a difficulty for this study to decisively identify causation or quantify correlation.

Analysis

Section 1: Reduction in demand for plastic waste from importing countries

This section outlines two factors in the international waste trade market that caused demand for Singapore's plastic waste exports to decrease. Namely, increased environmental awareness from importing countries and plummeting fuel prices have both made plastic waste exports, including Singapore's, less appealing. Note that this study will use "plastic scrap" interchangeably with "recyclable plastic waste," and "plastic waste exports" are all assumed to be recyclable.

1a: Changing Regional Attitudes

In January 2018, China introduced its infamous Operation National Sword, a ban on 24 different types of imported recyclable waste, alongside stricter regulations on plastic and mixed paper imports (Los Angeles County Public Works, 2018). At the time, China was the largest waste importer globally, and many countries directed the majority of their waste exports, especially plastic, to China. The EU collectively exported half of its total waste, 85% of which was directed to China (UNODC, 2023). Thus, adaptation was crucial.

The UN reported that "export weight of plastic scrap and waste fell by roughly 46% between 2017 and 2020, after the China ban, from around 12.3 Mt in 2017 to 6.4 Mt in 2020" (UNODC, 2023). Unfortunately, large waste exporters also redirected much of their remaining waste exports to Southeast Asia. plastic waste exports from the EU — previously reliant on China as mentioned before — to Indonesia "almost quadrupled" from 2017 to 2018, increasing from 50 thousand to 190 thousand tonnes. Some of these countries in the ASEAN region are also the main receivers of Singapore's plastic waste exports, especially Malaysia, Indonesia, and Vietnam. These 3 countries imported around 90% of Singapore's plastic waste exports from 2020 to 2022, so they will be the focus of any analysis involving importing countries (n.d., WITS).

This sharp rise in plastic waste trade had significant environmental drawbacks for ASEAN importing countries that often lack the appropriate "legal operators," infrastructure, or technology to deal with their own waste, let alone waste imports (European Environment Agency, 2019). For plastic waste to be recyclable, it must be high quality and uncontaminated. The quality of plastic is determined by "the degree of polymer-polymer mixing, presence of low molecular weight compounds and the degree of degradation" (Golkaram et al., 2022). Plastic waste that can be recycled also lacks any organic contaminants such as food, or non-organic contaminants like pesticides, that interfere with the quality of recycled plastic produced from plastic scrap (Undas et al., 2023). Unfortunately, imported plastic scrap that is theoretically of higher quality than domestic scrap is often insufficient quality or contaminated, and therefore cannot be used to create recycled products.

Poor municipal waste management and inadequate imports cause both high and low-quality plastic scrap imports to often be incinerated or thrown into landfills alongside domestic waste. These conditions mainly exacerbate two environmental issues. The first is the leakage of plastics into the ocean, due to plastic debris being swept into waterways from landfills or other places of disposal (Ng et al., 2023). The second is harm to citizens' health due to the incineration of low-quality plastic. For instance, one study found the "second highest level of dioxins from Asia ever measured" in eggs near a tofu factory in Indonesia that burned low-quality plastic as fuel, at levels 70 times higher than what was safe to ingest according to the European Food Safety Authority (Petrlik et al., 2019; Wood, 2018). Similarly, Malaysia had an influx of recycling factories that lacked operating licenses and used "environmentally harmful methods of disposal," as plastic that could not be recycled would either be burnt or sent to landfills (Chow, 2018).

These catastrophic consequences caused the ASEAN region to begin setting stricter regulations on waste imports. Malaysia, Indonesia, and Vietnam all adopted licensing or legal registration for plastic scrap-importing companies. Malaysia and Vietnam announced bans on certain kinds of plastic waste imports — similar to what China had done — in 2018 and 2019 respectively. Malaysia was set to implement its ban "within 3 years" and Vietnam planned to build up to a full ban by 2025. Instead of a ban, Indonesia restricted impurities in plastic waste imports since May 2020 (Rosengren & Pyzyk, 2018; Staub, 2019; Institute of Scrap Recycling Industries, 2021). Stricter regulations effectively signaled a reduction in ASEAN's demand for plastic waste imports, as it reduced the amount of plastic scrap that could be exported to these countries, including those of Singaporean origin.

The regional trend of decreasing demand due to environmental concerns, mostly starting around 2019 and persisting as incidences of illegal waste import activity continued despite more stringent regulations, was further reinforced by trade restrictions in the Coronavirus Disease of 2019 (COVID-19) pandemic (UNODC, 2023). Although not specific to Singapore, Southeast Asian countries' lowered demand for plastic scrap generally could have contributed to a reduction in Singapore's waste exports.

1b: The Prices of Fuel and Virgin Plastic Resin

Firms use plastic resins to make plastic products. Broadly speaking, there are two types of plastic resin. Virgin plastic resin is produced directly from crude oil or natural gas, containing no recycled material. Recycled plastic resin is created from plastic thrown away as waste either after use by a consumer, such as plastic water bottles, or by a firm, such as plastic boards (Don't Waste Services, 2022; CDDL Recycling, 2023). For the following section, "plastic items" refers to any consumer goods or packaging made from plastic, and "plastic resin" refers to plastic used to make these consumer-end products. "Virgin" and "recycled" will be used as differentiating qualifiers for the former two terms. "Recyclable plastic waste" refers to the unprocessed plastic waste that Singapore exports to be processed into recyclable plastic resin (Semula Asia, 2023b).

The COVID-19 pandemic led to economic stagnation that reduced global demand for oil, including crude oil. As a result, oil prices plunged drastically in 2020, with the price of West Texas Intermediate oil even becoming negative in April 2020 (Ebner & Iacovidou, 2021). Crude oil is a key factor of production for virgin plastic resin, so lower costs of production caused the price of virgin plastic resin to fall too (Ebner & Iacovidou, 2021). Virgin plastic resin is a direct substitute of recycled plastic resin in the production of plastic items, thus when virgin plastic resin became cheaper, demand for recycled plastic resin decreased.

Even before these drastic price changes, producers of plastic items almost always preferred virgin plastic resin to recycled plastic resin (Ebner & Iacovidou, 2021). Virgin plastic resin is generally higher quality than its recycled counterpart, able to "withstand high temperatures and pressure" during processing, while also being cheaper (Don't Waste Services, 2022). Without government intervention, recycled plastic resin is demanded very little in comparison to its competitors (Ebner & Iacovidou, 2021). Hence, the recycled plastic resin market relies on government support to be competitive, whether through investment into technology to improve quality, or through subsidies to lower prices.

To offset the lower demand for recycled plastic resin, extra government support for firms producing both recycled plastic resin and recycled plastic items would be especially critical. However, Indonesia, Malaysia and Vietnam's government budget deficits all severely worsened from 2019 to 2020 when the COVID-19 pandemic started, as illustrated in the graph below. Indonesia gradually raised its budget until it reached pre-COVID levels in 2022, but Malaysia's budget did not begin recovering until 2022, and Vietnam's deficit only worsened throughout the time period. Consequently, these governments were in no position to provide additional funding and investment to their recycling industries while they were affected by COVID-19.

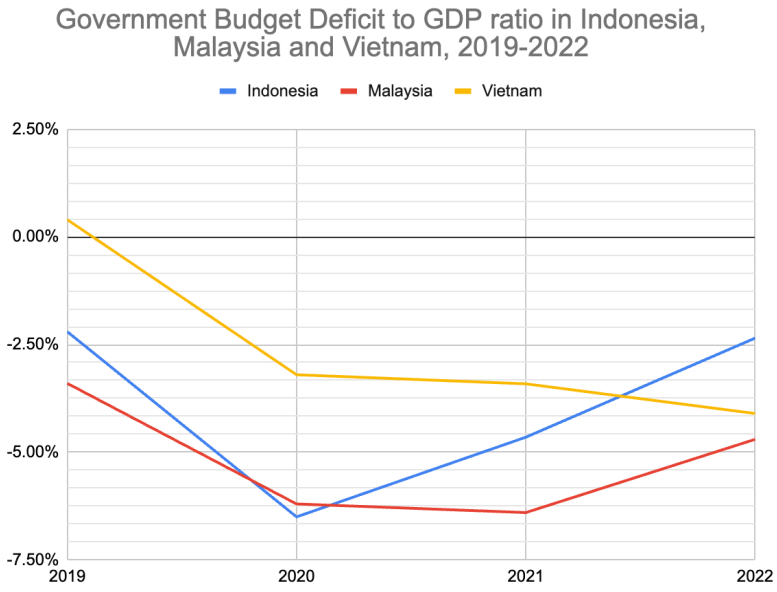

Figure 1 (Sources: Trading Economics, n.d.-a; Siddharta, 2024; Trading Economics, n.d.-b)

Because their existing budgets were strained, governments would have to raise tax revenue to be able to provide additional funding for the recycling sector. However, because of the socioeconomic impacts of COVID-19, governments generally focused on supporting their residents and bolstering their economy. Harsher tax policies would be counterproductive to these goals because higher taxes on firms could hinder economic activity while raising taxes that impact consumers could further worsen standards of living. Most governments relaxed their tax collection instead. Indonesia, Malaysia, and Vietnam all had tax exemptions for businesses, as well as tax relief for their citizens (Saptono & Khozen, 2022; Abd Rahim, Mohamed & Samuel, n.d.; Nguyen & Thanh Hoa Dao, 2021). For instance, Indonesia provided "compensation or bonuses" for medical and essential workers along with tax exemptions for some income groups, and Vietnam reduced its Value-Added Tax to make goods more affordable for consumers.

Because these governments were reducing all of their tax revenue streams for the benefit of their populations, they could not increase support for their recycling industries. Hence, lower demand would force producers to reduce the quantity of recycled plastic resin supplied, to maintain profits by lowering variable costs of production to not go bankrupt.

Imported recyclable plastic waste is a key raw material that Indonesia, Malaysia, and Vietnam use to create recycled plastic resin, as elaborated on in Section 4a. Demand for foreign plastic waste is reliant on the production of recycled plastic resin, the latter of which was severely endangered due to lacking government support when facing severe challenges from the virgin plastics market. Thus, demand for foreign plastic waste, including Singapore's plastic waste exports, would fall.

Section 2: Costs of production for waste exporting companies

The section below details indirect and direct factors that lead to an increase in the cost of production of plastic waste exports which are incurred by waste exporting companies.

2a: Regulations from SG and importing countries may increase bureaucratic red tape

The Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and their Disposal, shortened to The Basel Convention, is an international agreement to "protect human health and the environment against the adverse effects of hazardous wastes" (Basel Convention, 2011). Due to increasing concerns about the negative impacts of plastic waste trade detailed in Section 1, the Basel Convention was amended in 2019 to properly define and restrict harmful plastic waste exports, set to be effective in 2021 (Basel Convention, n.d.). As a signee of the Basel Convention, Singapore was obligated to adapt accordingly (National Environment Agency [NEA], n.d.).

Singapore adopted similar changes to that of the Basel Convention. An amendment to a bill specified a restricted list of the types of plastic waste that were permitted to be exported (Singapore Statutes Online, 2020). Regulations indirectly reduce firms' profits by increasing bureaucratic "red tape." These are costs of production incurred from firms' compliance with

regulations, which have been proven to impact firms' financial performance despite the exact costs being difficult to quantify (New York University Shanghai, 2024; Pellegrino & Zheng, 2024).

In terms of plastic waste exports, a company exporting plastic waste from Singapore to, for instance, Malaysia, would be forced to dedicate additional time and resources such as workers to catalog the type of plastic waste exported and to check that the exports are within regulatory standards for both countries. If regulations were not present, the firm could have instead hired workers to be used in production processes that would generate more revenue, or choose not to hire more workers at all to reduce wage costs.

Although regulations are an indirect cost of production, it is difficult for firms to circumvent the significantly tighter regulations from both Singapore and importing countries. Hence, these regulations are significant enough to raise the costs of production for firms exporting plastic waste.

2b: Freight costs (COVID and changing trends)

Freight costs are a more direct cost of production. Freight costs are incurred when waste exporting firms pay carriers to ship their waste overseas (DFreight, 2022). Due to the pandemic in 2020, many countries imposed lockdowns and restricted shipping to reduce the spread of COVID-19 (DHL, 2023). To compensate for related losses of revenue, freight companies increased their rates, reaching an "all-time high" approaching the end of 2021 (Elangovan & J-min, 2023). Because firms now need to pay for higher prices of shipping, a key component of waste exports, this further increases the cost of production of plastic waste exports.

2c: Impacts on supply

A firm's profit is determined by its revenue, minus its costs of production. So firms do not go bankrupt when costs of production increase, they may reduce how much they produce so that variable costs are reduced. Freight costs are a variable cost to waste exporting firms since the more plastic waste a firm ships overseas the more they need to pay. The only way to pay less would be to reduce the amount of plastic waste being exported, so the supply of plastic waste exports decreases.

Increased costs of production have a limited impact on supply. Section 3 demonstrates that there has been a dramatic increase in recyclable plastic waste generation in Singapore starting in 2020. As Section 4 will elaborate on, Singapore's recycling industry has limited capacity, unable to fully handle this significant increase in recyclable plastic waste. The only alternative would be to export the waste to be processed overseas, so waste exporting firms are unable to reduce supply to decrease the costs of production. To maintain profits, firms could instead increase revenue by raising prices, especially since demand is less sensitive to price changes as explained in Section 4. Therefore, the impact of increasing costs of production on supply of plastic waste exports is outweighed by the increase in supply of recyclable plastic waste.

Section 3: Supply of recyclable plastic waste in Singapore

Singapore's plastic recycling rate was 4% from 2019 to 2020, improved slightly to 6% in 2021, and remained at 6% in 2022 (NEA, 2023). Challenges to recycling amidst the COVID-19 pandemic caused low recycling rates despite greater environmental awareness. Still, the supply of recyclable plastic waste increased significantly.

Typically, the recycling of consumer end products is called "domestic recycling" whereas the recycling of waste from industry is "non-domestic recycling." These terms do not intrinsically separate waste that is exported and waste that is processed within its home country. Thus, waste recycling that occurs within its home country will be called "local recycling." This distinction is especially important for Singapore because it exports a significantly large proportion of its recyclable waste.

Plummeting fuel prices made virgin plastics much cheaper to produce in 2020, which was convenient for the large increase in single-use plastic consumption in the COVID-19 pandemic (Ebner & Iacovidou, 2021). In the short term, Singapore's medical industry in particular had large demand for plastics to minimize virus transmission. Hospitals required more personal protection equipment, such as gloves, medical masks and respirators, all of which often contain plastic. Furthermore, additional plastics were used "to decrease the risk of contamination and to facilitate cleaning," such as plastic sheets for covering exposed machines (J. Wong et al., 2020). Meanwhile increased plastic usage was also required for those living in Singapore, since the government implemented face mask mandates from April 2020 to February 2022 (Mohan & Lim, 2023).

Besides mask mandates, Singapore implemented other strict restrictions during the COVID-19 pandemic. From April to June 2020, a nationwide partial lockdown was introduced, where residents were only allowed to leave their homes if absolutely necessary, e.g. to exercise, or to provide essential services (Government of Singapore, 2020). Even after the lockdown, Singapore gradually loosened measures such as mandatory safe distancing between people, restricting group sizes, and limiting the proportion of workers allowed to go to their workplaces in person (Ministry of Health [MOH], 2022). Singapore only fully removed their COVID-19 restrictions around early 2023, until which the movements of both residents and firms were limited (MOH, 2023). Since recycling was not considered an essential service, the pandemic posed a great challenge to local recycling (The Straits Times, 2020). Recycling facilities had less freedom to perform services like waste collection, resulting in "delays to the recycling process" according to Jen Teo, executive director of the Singapore Environment Council (Elangovan & J-min, 2023).

Throughout the pandemic, residents were highly encouraged and sometimes forced to stay at home, causing them to resort to shopping online (Goh, 2022). The switch from physical purchases at restaurants and shops to online deliveries created an "emergence of sophisticated packaging and filling," dramatically increasing plastic waste. One survey even found that so many citizens ordered goods online and switched to disposable utensils "for convenience" that an extra 1,334 tonnes of plastic waste was generated over 8 weeks during the pandemic (Loo, 2021).

Consumers' behavior may have worsened recycling efforts for two reasons. First, the Singaporean government has implemented consumer nudges to encourage proper recycling, from the Recycle Right education campaign in 2019, to placing stickers on recycling bins instructing residents on what to throw inside, to distributing a mini recycling bin to each household (Elangovan & J-min, 2023). Despite these measures, 40 percent of waste in Singapore's recycling bins has remained unrecyclable since 2018, often because some residents contaminate the bins with food or liquid. Singapore's bins are co-mingling, meaning they contain multiple types of recyclable material including plastics, so bin contamination reduces recyclable plastic waste production.

Second, many consumers during the pandemic developed the perception that items are only sanitary when protected with single-use packaging (Ebner & Iacovidou, 2021). The resulting "rise in single-use plastics, beverage and food containers" has made "the correct sorting and disposal of recyclable materials" harder (Elangovan & J-min, 2023). Lots of single-use packaging mixes "biodegradable and non-biodegradable materials," further complicating recycling and therefore reducing the recycling rate.

However, some of the single-use plastics that have been used increasingly since the pandemic are recyclable when clean and dry, such as plastic cutlery and plastic packaging (Semula Asia, 2023a). Thus, COVID-19 lockdowns caused both recyclable and nonrecyclable plastic waste generation to increase significantly enough to offset the impacts of waste contamination.

In other words, consumers' hygiene concerns and online shopping caused such a high increase in recyclable plastic usage that it offset the low recycling rates. Hence, the quantity of recyclable plastic waste increased by 22 thousand tonnes from 2020 to 2021. The behavior of online shopping in particular persisted long-term, even after the pandemic (Ebner & Iacovidou, 2021). As a result, recyclable plastic waste generation plateaued from 58 thousand tonnes in 2021 to a similar 57 thousand tonnes in 2022 (NEA, 2023). So, despite consistently low recycling rates, the supply of Singapore's recyclable plastic waste still grew sharply because of COVID-19.

The increase in the supply of recyclable plastic waste is likely significant enough to overwhelm the limited capacity of Singapore's local recycling firms mentioned in Section 4. The resulting continued supply of recyclable plastic waste to waste exporting companies outweighs the increased costs of production explained in Section 2, so the supply of plastic waste exports as a whole would rise.

Section 4: Barriers to change

The section below argues that because both Price Elasticity of Demand (PED) and Price Elasticity of Supply (PES) for Singapore's plastic waste exports are inelastic, any factors will result in a less than proportionate change in quantity of plastic waste exported, thus contributing to the stagnating numbers.

4a: Reliance of importing countries on imported waste to run recycling

Despite detrimental environmental externalities and frequent contamination of imports, the plastic waste trade persists in Southeast Asia because importing countries are reliant on imported waste to recycle. Due to the aforementioned poor waste management, very little of the plastic scrap generated locally in Southeast Asian countries is high quality or uncontaminated enough to be used for recycled products.

For example, Xuan Quach, the Country Director of Pacific Environment Vietnam, highlighted that Vietnam has a "shortage of plastic scrap," citing factors like "limited domestic plastic waste collection and sorting infrastructure" and "insufficient recycling capacity," both of which would likely deteriorate the quality of plastic scrap (Hub & Khare, 2024). Despite "efforts to increase domestic recycling rates and reduce reliance on imported plastic waste," the need to import high-quality plastic scrap, often from more affluent countries, persists (Hub & Khare, 2024). Similarly, plastic waste importing is "necessary" to "produce recycled products" due to "low domestic recycling rates" in Malaysia. Firms producing recycled plastics most prefer to use imported plastic as raw material because of its "guaranteed supply, lower price, large volumes and homogeneous resins." Contrastingly, "municipal" plastic waste is the "last choice," even behind local industrial rejects, due to "high level of impurities, higher buy-back cost, and inconsistent quality" (Chen et al., 2021).

Southeast Asian reliance on foreign plastic scrap reduces the impact of price changes on their demand for plastic waste imports. On one hand, there is a lack of available substitutes. Even though imported plastic scrap became more expensive, countries could not switch to locally generated plastic scrap due to its inadequate quality. On the other hand, imported plastic waste is a key factor input for plastic recycling facilities, hence it is a necessity: imports would continue even if prices rose because otherwise, the recycling sector would collapse. Lack of available substitutes and necessity are both factors contributing to inelastic PED, which means that consumers of Singapore's plastic scrap are less responsive to changes in price. As illustrated in the diagram below, if the price of Singapore's plastic scrap increases (P to P_1) perhaps due to producers passing on the higher costs of production, quantity demanded falls (Q to Q_1) but it is proportionately less than the increase in price.

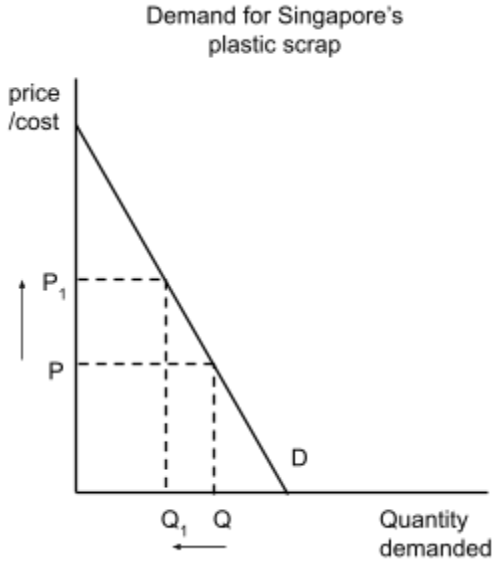

Figure 2: inelastic demand

We may note that the PED of Singapore's plastic scrap specifically will be less inelastic than the PED of plastic scrap as a whole since there are available substitutes. While importing countries have no alternative for plastic scrap, they can buy it from other exporting countries that provide significantly higher quantities of plastic scrap exporters than Singapore. This includes the USA, the top importer of Malaysia and a significant importer to Indonesia, Australia, a main importer to Indonesia, and EU member states, highlighted prior as main importers to the ASEAN region (TrendEconomy, 2024; Alves, 2024; UNODC, 2023).

However, Singapore arguably makes up for its small quantity of exports with quality. There is only one reported instance of an importing country, namely Malaysia, sending plastic waste imports back to Singapore. Despite Malaysia reporting 4 containers of waste returned to Singapore, the 3 containers of waste received did not violate the Basel Convention, nor did the Singaporean exporter violate any rules. Rather, the Malaysian importer had "failed to get permits" (Lee, 2020). For comparison, Malaysia had shipped a total of 150 plastic waste import containers back to the origin countries by 2020 for inadequate permits, violations of the Basel Convention criteria, or both. EU members France and Spain accounted for 43 and 10 containers respectively, while the USA received 17 containers (Hassan, 2020; Latiff & Harris, 2019). Similarly, Indonesia's waste imports were often contaminated, but Singapore has no recorded cases of returned waste shipments due to contamination (Paulo, 2020).

While it is plausible that Singapore had similar instances that were not recorded, there is still a lack of complaint about Singapore's plastic waste exports in comparison with previously outlined competitors. We can therefore deduce that Singapore's plastic scrap is of higher quality than its competitors'. Because high-quality plastic scrap specifically is the key input for recycling industries, importing countries may choose to keep buying Singapore's plastic scrap instead of switching to competitors even if the price increases. The quality of Singapore's plastic scrap gives Singapore an advantage over other exporting countries, hence the PED for Singapore's plastic waste exports can still be considered inelastic.

4b: Lack of spare capacity (alternative waste processing methods) → price inelastic supply of plastic waste exports

Just as its importing countries are reliant on imported plastic scrap, the export of plastic waste is crucial for Singapore's waste management. The main alternative to exporting recyclable plastic waste is to recycle locally. The Straits Times highlights some "local constraints" for recycling locally as "high operational costs, manpower shortage and space" (Begum & Hong, 2023). Due to these factors, Singapore only has a small number of private firms that recycle locally (Yabuka, 2024). Hence, from 2020 to 2022, Singapore did not "have the capacity" to recycle more waste (Elangovan & J-min, 2023). In other words, with existing resources, Singapore would find it difficult to locally recycle significantly more of the plastic waste that was supposed to be exported. This lack of spare capacity cannot be compensated for quickly because new infrastructure takes a long time to build. For instance, the redevelopment of one of Singapore's recycling parks to "improve land use and land productivity" was announced in 2023, scheduled to be complete by 2029 (Tan, 2023). Because building new facilities to increase Singapore's recycling capacity entails a time lag, existing resources cannot be quickly generated to process an increased amount of plastic waste.

Besides local recycling, the other alternative to exporting plastic waste is Semakau Island, Singapore's landfill for the ash of its incinerated waste. However, this is an undesirable substitute because of the negative environmental impacts of landfill waste detailed in Section 1. Also, it would go against "efforts to extend the life" of the landfill, which is currently predicted to reach maximum capacity by 2035 (Oberai, 2023; Elangovan & J-min, 2023).

Overall, local recycling facilities lack the capacity to take on much more plastic waste, and landfilling is avoided when possible. Therefore, there is a lack of close substitutes for exporting plastic waste, which makes Singapore reliant on the plastic waste trade. The majority of its recyclable plastic waste was exported throughout the time period, reinforcing the lack of substitutes. There were no percentages officially published by the NEA, but we can compare data from Our World in Data on Singapore's plastic waste exports to the NEA's data on the amount of recyclable plastic waste generated to see that Singapore has consistently exported the majority of its recyclable plastic waste (in chronological order, 96.4%, 56.0%, 60.9%), even with all the regulations set.

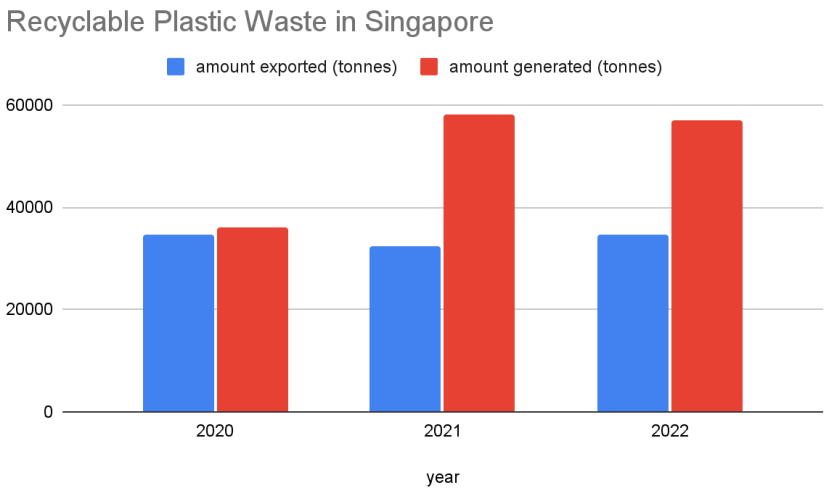

Figure 3: chart comparing exported recyclable plastic waste to total recyclable plastic waste (NEA, 2023; Ritchie, 2022)

The PES of Singapore's plastic waste exports is inelastic too: even if overseas demand is falling rapidly and costs of production rise as discussed in Section 2, lack of spare capacity and long time lags to create spare capacity make it difficult to quickly reduce its international supply of plastic waste. This means that producers, which in this case are Singaporean plastic waste exporters, are also relatively unresponsive to changes in price. For instance, if the price decreases due to lower demand for Singapore's waste exports (P to P_1), the quantity supplied will decrease proportionally less (Q to Q_1). This limits the impact that any changes in price have on the supply of plastic waste exports from Singapore.

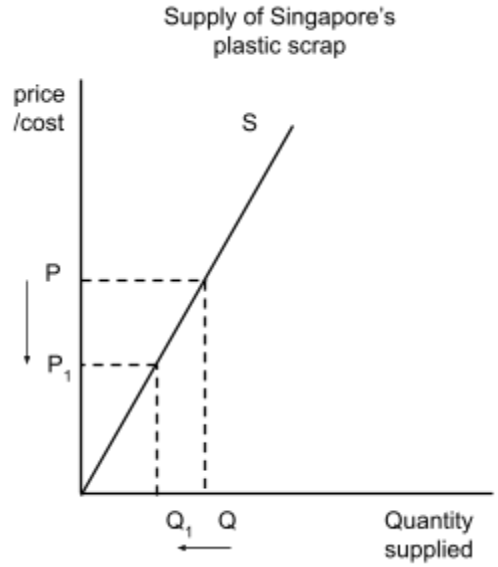

Figure 4: inelastic supply

Section 5: The market as a whole

We will now use the microeconomic price mechanism to model how different factors led to the stagnation of Singapore's plastic waste exports. The below diagram is an approximate illustration of the situation:

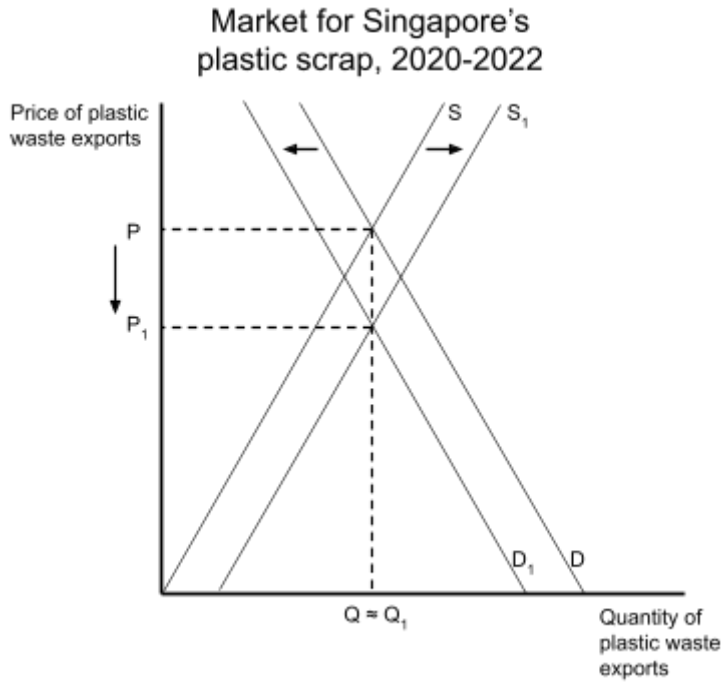

Figure 5: Model for Singapore's plastic waste export market

In the model, variables D and S are the original demand and supply curves respectively for Singapore's plastic waste exports in 2020. Variables D_1 and S_1 are the demand and supply curves respectively in 2022. Q and Q_1 are the market equilibrium quantity of Singapore's plastic scrap traded in 2020 and 2022. They are displayed as the same point in the model because the quantity of Singapore's plastic waste exports in 2020 and 2022 are extremely similar. Finally, P and P_1 are the theoretical prices of Singapore's plastic waste exports in 2020 and 2022 respectively. The demand and supply curves for Singapore's plastic waste exports are illustrated with steep gradients because both are price inelastic.

In Section 1, we established that importing countries' demand for Singapore's plastic scrap has decreased. On one hand, importing countries have increased awareness of the harm from the plastic waste trade, causing a shift in preferences that makes foreign plastic scrap less desirable. On the other hand, the dramatic decrease in price of virgin plastic resin, a higher quality substitute for recycled plastic resin, has reduced demand for recycled plastic resin, and hence reduced the derived demand for imported plastic scrap. Changes in preferences and price of substitutes are both non-price determinants of demand, which are factors unrelated to price that impact demand. Whereas price changes cause movements along the demand curve, these non-price determinants of demand shift the demand curve as a whole to the left (D to D_1).

However, the decrease in demand is relatively small, because both factors of demand have limited impact. First, even though environmental attitudes have changed, importing countries' reliance on waste imports to sustain their recycling industries still makes it difficult to deter plastic waste imports. Therefore, the region's reliance on imported plastic scrap limits the reduction in demand. Second, even if virgin plastic resin became more price competitive, recycled plastic resin production relies on government support. Governments had little ability to further invest in the recycling industry amidst the pandemic. Nevertheless, the existence of government support means that some portion of recyclable plastics production is guaranteed regardless of market movements. By extension, low virgin plastic prices cannot reduce demand for the imported plastic scrap used to create recycled plastic resin past a certain point. Consequently, effective demand will not decrease to a large extent.

Sections 2 and 3 elaborated on contrasting non-price determinants of supply, namely costs of production and supply shock. Increased costs of production reduce the supply of Singapore's plastic waste exports. Meanwhile, hygiene concerns and e-commerce in the COVID-19 pandemic were a positive supply shock that increased recyclable plastic waste generation, which Singapore would have to export most of due to limited recycling capacity, thereby increasing supply of plastic waste exports. Similarly to demand, non-price determinants of supply cause the supply curve to shift.

Overall, the supply of Singaporean plastic waste exports increases, and the supply curve shifts right (S to S_1). Recyclable plastic waste, a key constituent of plastic scrap exports, increased by more than 50% during the pandemic. Singapore had limited ability to increase local recycling quickly enough to fully compensate for the influx of recyclable plastic waste, which means most of it has to be exported instead. Even if firms want to export less to cut costs, they would still be forced to produce plastic waste exports. Hence, supply would increase because the need to export recyclable plastic waste outweighs complications from increased regulations and freight costs. However, because these factors are counteracting each other, supply will only increase by a small amount.

Because both the demand and supply shifts are small, we can assume they are similar in size. Thus, after the demand curve shifts to the left and the supply curve shifts to the right, quantity traded remains at its original position of Q. This is in line with Singapore's plastic waste exports at the beginning and end our time period, exporting 34704 tonnes in 2020 and stagnating at 34710 tonnes in 2022 (Ritchie, 2022).

Though the diagram shows price decreasing (P to P_1), data from the World Bank shows that price per kilogram of plastic waste has increased throughout the time period of 2020 to 2022 (n.d., WITS). Because demand and supply are both price inelastic, any factors could lead to the market experiencing large changes in price with negligible changes in quantity traded. Especially because of high price volatility, the magnitude of identified shifts in demand and supply is perhaps too small to definitively dictate how prices will change. This leaves room for other factors that may not be significant enough to directly shift supply or demand to still result in large price changes.

Specifically, higher costs of production are the outweighed factor in shifting supply. As mentioned in Section 2, a firm may raise profit by either cutting their costs of production or by raising revenue. Because plastic waste exporting firms cannot reduce their production to cut variable costs, they may be forced to increase revenue instead to maintain their profits. Revenue is calculated by multiplying the price of the product by the total quantity demanded, and hence sold. Price and quantity demanded have an inverse relationship such that increasing price would cause quantity demanded to fall.

However, as Section 4 highlighted, inelastic PED means that when price increases, quantity demanded falls proportionally less than price increases. Therefore, due to inelastic PED, the additional revenue gained from raising prices will be greater than the revenue lost from lower quantity demanded, and plastic waste exporting firms will overall gain more revenue by raising prices. Knowing this, firms may decide that setting a higher price that can cover their increased costs of production is more beneficial than setting a lower price, which may risk the firm making a loss or shutting down despite better adhering to demand and price signals. As a result, prices increase against the predictions of Figure 5.

The discrepancy between price changes in the model and price changes in real life may reflect a shortcoming of the microeconomic model. Though it accurately represented the impacts of identified economic factors on the quantity traded of Singapore's plastic waste exports, it may be too simplistic to take any additional impacts on price into account.

Overall, increased environmental awareness and competition from virgin plastic has caused demand to decrease, while the influx of plastic waste due to COVID-19 caused supply to increase despite increased costs of production, in part due to Singapore's reliance on importing countries to process its waste. This caused quantity traded to remain constant, as displayed in the model. Contrary to the model's prediction of price decreasing, costs of production lead to increased prices while minimally impacting quantity demanded due to price inelasticity.

Conclusion

This study has identified and examined the economic factors that caused Singapore's plastic waste exports to suddenly stagnate from 2020 to 2022. This study contributes to the literature by investigating the plastic waste trade situation in Singapore, a country that is often overlooked in research on the plastic waste trade. This study's findings may provide insights into challenges to changing Singapore's plastic waste export situation, from global factors like changing environmental attitudes and COVID-19-related supply shocks to local factors like Singapore's lack of recycling capacity. Observing how these recent developments affect Singapore specifically may provide insights for policymakers or other relevant actors to improve Singapore's waste management, while perhaps providing inspiration for action in other countries.

Due to lack of access to primary data, the paper had limited ability to definitively quantify impacts of the factors identified. Further research may therefore include an attempt to quantify these economic factors, especially in relation to changes in the market. Additionally, this paper chose to focus on plastic waste exports specifically, but the trade of other types of waste may be

worth investigating in further research, too. Due to focusing on analyzing the situation, this paper also does not suggest or evaluate policies that can improve the situation. Thus, further research to evaluate current and future solutions is critical.

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