



A framework for selecting and designing policies to reduce marine plastic pollution in developing countries

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ABSTRACT

The polluting of marine ecosystems with plastics is both a global and a local problem with potentially severe consequences for wildlife, economic activity, and human health. It is a problem that originates in countries' inability to adequately manage the growing flow of waste. We use an impact pathway framework to trace the flow of plastics through the socio-ecological system and identify the role of specific policy instruments in achieving behavioral changes to reduce marine plastic waste. We produce a toolbox for finding a policy that is suitable for different countries. We use the impact pathway and toolbox to make country-specific recommendations that reflect the reality in each of the selected countries.

1. Introduction

Marine plastic pollution is a global transboundary problem that originates at a local level and that has captured increased political and scientific attention over the last decade (UNEP, 2016, 2009). Marine plastic pollution has many negative consequences. One is that animals, in particular turtles, mammals, and sea birds, ingest or get trapped in plastic waste (Thompson, 2015). Research also shows the presence of plastics in fish that humans consume (Bonanno and Orlando-Bonaca, 2018; Rochman et al., 2015). However, no research has confirmed or disproved that this poses a risk for humans (Carney Almroth and Eggert, 2019; Rist et al., 2018). There are also aesthetic costs caused by plastic pollution, both near shores and in the oceans, including the Great Pacific garbage patch (Lebreton et al., 2018). Jambeck et al. (2015) predict that with current policies and per capita waste generation, the volume of plastics entering the sea will double by 2025.

In this paper, we focus on the design of policies to reduce marine plastic pollution. Our focus is on the local level, although some of the

policies can have transboundary effects. We do recognize that local actions will not be sufficient. Thus, the problem should be addressed by a combination of global and local policies (Haward, 2018; Löhr et al., 2017; Jambeck et al., 2015; UNEP, 2017). Various multilateral agreements and United Nations (UN) resolutions have been put in place, in particular from 2007 and onward, yet their impact seems to be very limited so far (see, e.g., Dauvergne, 2018; UNEP, 2017). Tessnow-von Wysocki and Le Billon (2019) propose seven elements to develop and inclusive global treaty that can help overcome the challenges to eliminate marine plastic pollution.

We focus on developing countries. A large amount of marine plastic waste originates in such nations (Jambeck et al., 2015). Solid waste management practices in developing countries are highly heterogeneous, with greatly varying levels of treatment, low recycling rates, and a high share of illegal disposals.

In Section 2, we present an impact pathway framework that allows for the identification of key policy entry points and for country-specific recommendations that reflect the institutional characteristics at hand.

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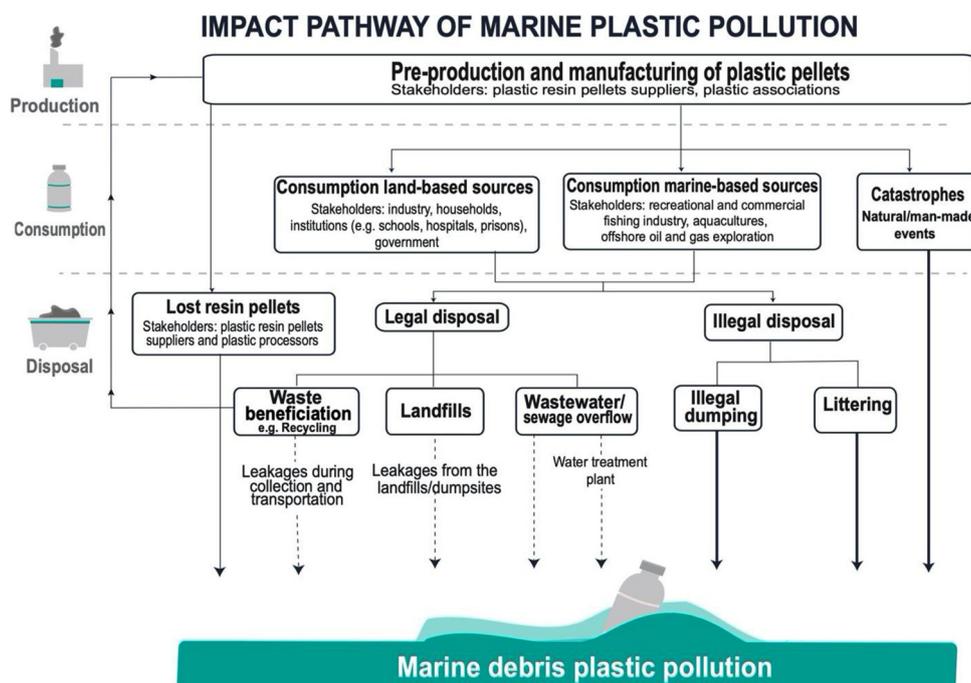


Fig. 1. Impact pathway of plastics into the ocean and key policy levers.

In Section 3, we review policy instruments for reducing marine plastic pollution. This includes instruments based on monetary incentives and command-and-control, but also soft interventions based on insights from behavioral economics. In Section 4, we apply the impact pathway framework and policy review in six developing countries with different characteristics and therefore representing different points in the impact pathway: Tanzania, Vietnam, South Africa, India, Costa Rica, China, and Chile. A key contribution of this paper is the provision of country-specific recommendations for improvements. Moreover, we focus on one problem with plastics, namely the pollution of the oceans with long-lived plastic debris. Although we recognize their importance, we do not discuss all the other possible negative aspects of the production, consumption, and disposal of plastics.

2. Impact pathway of marine plastic pollution

Fig. 1 shows the pathways of plastics from the first stage of the manufacturing of resin pellets to the loss or disposal of plastics into the marine environment. There are primarily three stages at which plastic waste enters the ocean: production, consumption, and disposal.

The first pathway into the ocean is the one originating in the production and transformation of plastic resin pellets, where inputs like oil and natural gas are turned into a plastic resin, which in turn is transformed into plastic products (Mahdi, 2013). In 2014, the global plastics production was estimated to total 300 million metric tons per year (Jambeck et al., 2015; Löhr et al., 2017). The production, transportation, and transformation of pellets into actual plastic products can cause leakages of resin pellets into the oceans. Signs of this are found in environmental samples all over the world (Karlsson et al., 2018; Law, 2017).

In the consumption stage, plastic products are purchased, consumed, and ultimately discarded. The consumption stage influences both the upstream and the downstream: By reducing the demand for plastic products, plastic waste from both production and disposal is reduced. There are two pathways through which plastics end up in the oceans, i.e., land-based and marine-based sources, each of which contributes 80% and 20% of the total debris, respectively. However, no studies have quantified the relative contributions of all critical sea-based sources (Geyer et al., 2017).

Land-based sources of marine pollution contribute between 4.8 and 12.7 million tons every year (Jambeck et al., 2015), originating from a variety of sectors such as construction, households, packaging, and coastal tourism (UNEP, 2016). For example, plastic consumption in households includes the use of plastic bags, single-use plastics, plastic containers, and plastic furniture, but also microplastics in cosmetics, glitter, microfibers from textiles products, and toothpaste. Given the complexities involved in proper disposal of plastics – e.g., chemical pollution and long-lived components (Galloway et al., 2017) – some authors claim that the main solution is to reduce the actual consumption of plastics, targeting first all areas where suitable substitutes are available or potentially available (Lebreton and Andrady, 2019; Zheng and Suh, 2019).

Marine-based sources of plastic pollution include commercial fishing, recreational boaters, and offshore oil and gas platforms (Sheavly and Register, 2007; Thevenon and Sousa, 2017). The pollution is mainly due to lost gear or cargo and the discharge of waste during normal shipboard operations. Although the latter practice is prohibited under Annex V of the International Convention for the Prevention of Pollution from Ships, it only applies to vessels of signatory nations (Raubenheimer and McIlgorm, 2018). To date, no global estimates of plastic pollution from any of the marine-based activities are available, but some argue that their contribution to floating debris is significant (Ryan et al., 2019). The pathway from marine-based sources to marine debris is particularly important for countries with large fishing fleets, especially if those fleets are mostly informal or artisanal and if the country does not have the port facilities for collection of waste.

Disposal of plastics can be divided into legal and illegal disposal. Precisely what constitutes legal and illegal varies across national legislations. This fork in the impact pathway is important since illegal disposal is a direct route to the oceans that the government cannot control. There are three forms of legal disposal: *beneficiation* (i.e. recycling or incineration), *landfill/dumpsites*, and *wastewater treatment*. From these forms of proper disposal, there could still be leakages into the marine environment during collection and transportation.

An important aspect of waste beneficiation is recycling, which focuses on collecting plastic waste to be reprocessed and reused in some other form. It is essential to understand the complexity inherent to plastics as a material. It consists of many different materials, chemically

dissimilar polymers, chemical contaminants, and additives together. Thus, recycling of plastics is not as easy as just grinding and melting plastics into something new, and this is a major obstacle to safe and economically viable recycling.

In countries where recycling has been established, plastics are often collected via curbside collection and/or drop-off centers (Guagnano et al., 1995; Sidique et al., 2010). At material recovery facilities, plastics are sorted in order to increase the recycled product quality and value (American Chemistry Council, Inc., 2018). This type of waste beneficiation reduces both the amount of waste deposited into landfills and the need for raw materials to produce plastics.

Landfills and dumpsites range from sophisticated technological landfills to open-air dumpsites, so the fact that solid waste is collected and transported to such sites does not by any means guarantee that no particles will leak into the ocean. Torrential rain, landslides, wind, and people might still cause pollution of waterways and, eventually, the oceans. Finally, we include a legal form of wastewater discharge in the impact pathway. Households' wastewater contains plastic microbeads, which are residues from personal care products and fibers from synthetic clothing. Such microbeads require specific wastewater treatments to avoid discharge into the environment (Browne et al., 2011). Recent studies show that new water treatment technologies can effectively decrease microplastics in the effluent by 98% (Mintemig et al., 2017; Murphy et al., 2016). However, developing countries lack this technology (Zhang et al., 2016).

Illegal forms of disposal contribute directly to marine plastic pollution and include illegal dumping and littering. In developing countries, waste management facilities are not always available, and solid waste is often dumped in large open areas or directly into rivers. Some waste, like plastic bags, is easily carried by wind and rain into waterways, and from there into the ocean.

Lastly, Fig. 1 mentions plastic pollution originating from catastrophic events, including earthquakes, tsunamis, hurricanes, and floods. When these catastrophes occur, large amounts of material from urban and rural areas enter the marine environment. From a policy perspective, not much can be done about these sources of pollution.

3. Problem identification, definition of policy goals, and a menu of instruments

We distinguish between four broad types of instruments: 1) price-based instruments, which change the relative price of goods or inputs associated with plastic pollution, either by taxing them or subsidizing alternative, less polluting goods or inputs, 2) rights-based instruments, in which a total allowable quantity of pollution is determined, and trade in pollution rights is allowed to minimize the cost of pollution reductions, 3) regulation, which directly determine allowable pollution levels, and 4) behavioral instruments, which use people's social preferences and/or cognitive limitations to influence behavior in favor of lower plastic pollution. A complex problem like plastic pollution typically requires a mix of policy instruments.

From a policy design perspective, waste has three critical complications. The first is the classic "missing market" problem: in order to enable markets to assist with waste management efforts, property rights for waste must be clearly defined in the sense of who owns the waste and is therefore responsible for it. Typically, they are not. The second concern is a moral hazard: putting too much pressure on actors to reduce waste or increasing the price of legal disposal could lead to illegal dumping, which is mostly unobservable. Third, plastic pollution is a problem of the commons, i.e. that each individual action is largely insignificant, while the sum of all of them leads to decreased welfare for everybody.

Fig. 2 provides guidelines on how to set policy goals based on the impact pathway of plastics described above.

Identifying a problem is the first step in solving it. Policymakers should be able to identify the fundamental problems and hence the

desired policy goals by looking at a limited, simplified set of indicators. Fig. 2 suggests a few possible indicators for each step of the impact pathway, such as share of treated wastewater. It includes indicators drawn from the literature and expert opinion. For example, if the balance of trade for plastics is positive, indicating substantial local plastic production, and if the industry predominantly consists of small or informal enterprises, then policies are needed to ensure that pellets are not lost during transport and processing and that plastic products are redesigned to take explicit account of their end-of-life uses and re-uses and/or decomposition.

Jambeck et al. (2015) estimate that, on average, 0.2 kg per person per day (ppd) of plastics is consumed worldwide. Sri Lanka is the worst country (5.0 kg/ppd), followed by the U.S. (2.59 kg/ppd) and South Africa (2.0 kg/ppd). China and India have consumption levels of 1.10 kg/ppd and 0.34 kg/ppd, respectively. The top 10 countries in terms of environmental performance have consumption levels of about 0.16 kg/ppd (Wendling et al., 2018). In our analysis, we propose that countries should at least strive to achieve plastic consumption figures below the global average.

Littering and illegal dumping of waste require special attention (Willis et al., 2017), as illegal disposal of plastics almost certainly leads to pollution of oceans. There are estimates suggesting that more than 20% of the world's plastic waste is mismanaged (Jambeck et al., 2015). Even if waste is properly collected and managed, the risk of leakage will remain, as long as water treatment plants do not have the proper technology to capture microplastics and landfills do not have mechanisms to prevent it. The challenges in managing plastic waste are enormous, highlighting the importance of waste beneficiation. A recycling/reuse target of no less than 20% of all collected waste should be the aim of policymakers (Geyer et al., 2017).¹

With the problems and policy goals identified, the next step is to choose the combination of policies (see Sterner et al., 2019 and Sterner and Coria, 2012 for full overviews). To date, the most commonly used instruments are price-based instruments aimed at reducing the costs of recycling or increasing the cost of plastics, and regulatory policies.

Fig. 3 gives an overview of current and potential policy instruments placed explicitly in the three major parts of the impact pathway. We distinguish between price-based, rights-based, regulation, and behavioral instruments.

A key feature of the impact pathway of plastics is that it illustrates how different targets and actions are interconnected, calling for the design of policy packages or policy mixes, rather than isolated efforts. Policies need to be attentive to these interconnections or will run the risk of severe perverse effects. For example, when illicit dumping of waste is an option, any pricing of solid waste collection and/or compulsory recycling targets might result in increased illicit dumping (Fullerton and Kinnaman, 1995). We will revisit this point in Section 3.5.

3.1. Price-based instruments

Price-based instruments aim to raise the price of a good or an input, relative to less damaging alternatives, in order to discourage its use. The existence of a market with adequately defined property rights and observable transactions is an absolute requirement for the use of price-based instruments.

3.1.1. Targeting the plastic industry

Under ideal conditions, a tax per unit of emissions would be the optimal policy to reduce spills from the production of pellets and the manufacturing of plastics, i.e., firms would have to pay a tax per unit of

¹ In 2014 the worldwide average recycling rate of used plastics was around 18% (Geyer et al., 2017). The average recycling rate for developed countries was around 29% (Kaza et al., 2018).

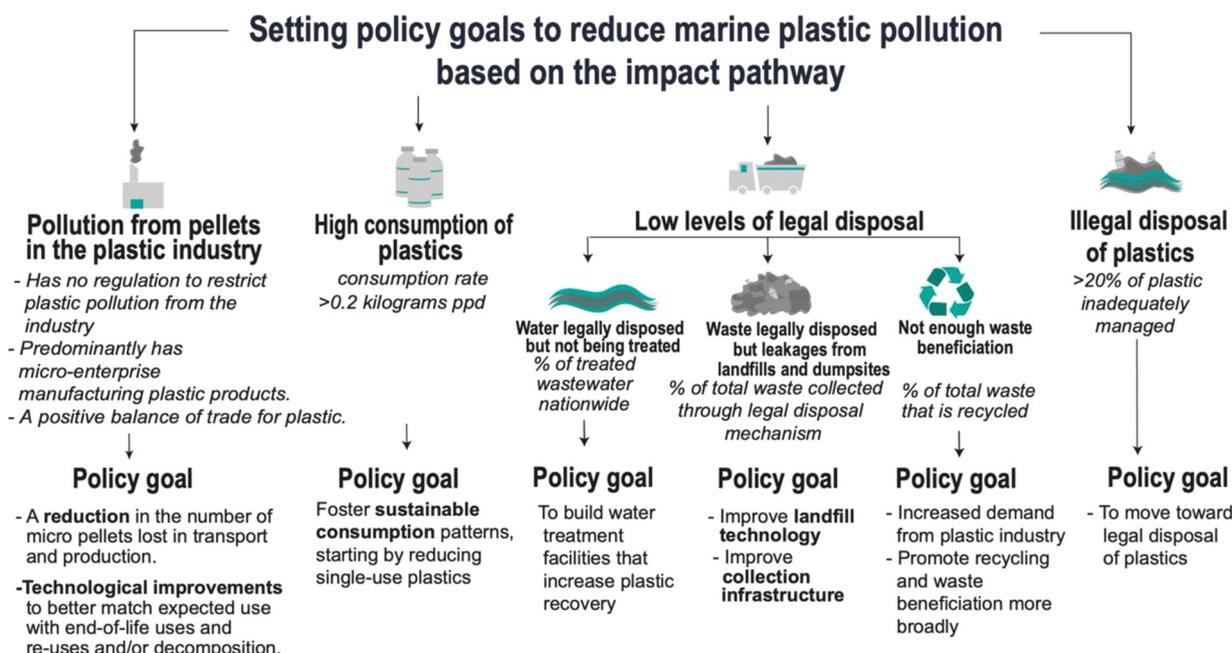


Fig. 2. Identifying policy entry points and setting policy goals.

| | Price-based instruments | Rights-based instruments | Regulation instruments | Behavioral instruments |
|--|---|---|---|--|
| <p>Targeting the plastic industry</p> | <ul style="list-style-type: none"> - A tax based on environmental performance of the plastic products. - Subsidies for research and innovation. | <ul style="list-style-type: none"> - Extended producer responsibility (EPR). | <ul style="list-style-type: none"> - Standards for pellets spills from the industry. | <ul style="list-style-type: none"> - Information provision. - Nudging such as setting defaults to “no plastics”. - Use of social comparisons. |
| <p>Targeting consumption of plastic by households and firms</p> | <ul style="list-style-type: none"> - Increasing the price on plastic products. - Deposit-refund schemes for plastic bottles. - Waste charge. | <ul style="list-style-type: none"> - Waste-based billing. | <ul style="list-style-type: none"> - Bans (single-used plastic, light-plastic bags). - Mandatory recycling. | <ul style="list-style-type: none"> - Information provision. - Nudging such as setting defaults to “no plastics”. - Use of social comparisons. - Explicit use of social norms. |
| <p>Targeting disposal of plastics</p> | <ul style="list-style-type: none"> - Weight-based pricing of waste. - Subsidizing appropriate behavior. | <ul style="list-style-type: none"> - Extended producer responsibility. - “Pay-as-you-throw” (PAYT) systems. - Provision of waste collection that promotes separation of waste for recycling. | <ul style="list-style-type: none"> - Landfill bans. - Mandatory recycling laws. | <ul style="list-style-type: none"> - Education, information campaigns. - Information appealing to social and personal norms, pro-social behavior. - Door-to-door information provision. - Face-to-face information facilitating the adoption of recycling. |

Fig. 3. Problem-based selection tool.

plastic emitted into the ocean. In practice, however, emissions are challenging to monitor, and it can be difficult to trace them to the right source. Therefore, taxes could instead be linked indirectly to the environmental damage of the products or to how recyclable the components of the products are. For example, a government can set higher taxes on polymers with more significant health impacts (like PS or PVC), or can tax certain additives. Subsidies are, to a large extent, the opposite of taxes: firms’ products could get a subsidy if they meet specific criteria such as a certain reduction in plastic pollution.

3.1.2. Targeting plastic consumption

Increasing the price of products with high plastic content or putting a price on plastic as an input has at least three indirect effects on plastic pollution: (i) decreased production of plastics and as a result less pollution from the production, (ii) less plastic waste and as a result less pollution from the waste generation, and (iii) reduced illegal disposal

because of a higher value of plastics. Various ways to increase the price of plastics have been used in many countries, in particular for single-use plastics. Examples include Botswana, Denmark, Ireland, China, and South Africa (He, 2012; Kish, 2018). The most famous and widespread case is the levy on plastic bags, which was first introduced in Ireland in 2002 (Convery et al., 2007). There is extensive evidence of a significant reducing effect of this measure on plastic bag consumption and a positive effect on the use of reusable bags (Jakovcevic et al., 2014; Luís and Spínola, 2010; Martinho et al., 2017; Wagner, 2017). However, the literature suggests that levies on plastic bags implemented without other reinforcement instruments such as education programs and information campaigns are only effective in the short run (Dikgang et al., 2012; He, 2012; Nahman and Godfrey, 2010; Zen et al., 2013) and may suffer from a rebound effect in the form of an increase in the purchase of plastic garbage bags (Dikgang et al., 2012; Martinho et al., 2017; Wilcox et al., 2016).

Policy instruments can also tackle the consumption of marine-based waste-generating products. Taxes and charges for port reception and ship berthing and commercial and recreational fishing fees directly affect the consumption and disposal of plastics (Ten Brink, 2009).

3.1.3. Targeting disposal of plastics

There are two main targets for the disposal of plastics. The first is to reduce plastic waste per se. The second is to increase the extent of appropriate disposal. The price-based instrument for reducing waste is to influence the cost associated with waste, for example via weight-based pricing of waste or a “pay-as-you-throw” system (Oosterhuis et al., 2014). The risk with this, in particular with weak institutions and no strong norms associated with doing the right thing, is that it increases illegal disposal. Weight-based pricing of waste collection, for example, could increase illegal dumping (Dahlén et al., 2007; McIlgorm et al., 2011).

Price-based payments have also been used to reward the right behavior. Two examples are payments to vessels to incentivize discharge before departure (Matthysen and Spolander, 2007; McIlgorm et al., 2011) and reward payments to fishers for the collection of marine litter (Cho, 2009; Ten Brink, 2009).

3.2. Rights-based instruments

3.2.1. Targeting the plastic industry

Extended producer responsibility (EPR) is the main rights-based instrument used. EPR assigns property rights, and hence duties, to the producer of plastic products for the treatment and disposal of these after consumption. The goal is to encourage a reduction in the volume of waste and in the use of virgin materials, and to develop the recycling sector (Brouillat and Oltra, 2012). The EPR approach is being implemented in the European Union, where governments require increased plastic recyclability in product design, e.g., fewer polymers in products, fewer mix-polymer composite products (like chips bags), fewer chemical additives, and increased transparency concerning additives. In the European Union, all plastic products should be recyclable by 2030 (Gilli et al., 2018).

3.2.2. Targeting plastic consumption

In our extensive literature review, we could not find a single example of rights-based approaches targeting the consumption of plastics. The one that comes closest, and as discussed below, is a deposit refund scheme. Under a deposit refund scheme (for glass bottles, cans, or plastic bottles/containers), the consumer purchases both the right to the content and the right to the container. As a result, the retail price of the product is relatively higher, discouraging consumption, unless the right to the container can be “sold” to a collection point. But even if there is a right to sell, the fact that there is a time lag and associated transaction costs between the purchase and the sale of the container results in a higher effective price for goods under a deposit refund scheme, and hence lower consumption.

3.2.3. Targeting disposal of plastics

A key component explaining the lack of proper waste disposal is that there is a “missing market.” One rights-based instrument that creates a market is a deposit-refund scheme. By assigning a monetary value to waste, a deposit-refund scheme not only promotes recycling but also creates incentives for picking up trash, since the trash now has a value. Bell et al. (2010) and Viscusi et al. (2011) find that deposit-refund schemes for plastic bottles are strong incentives to increase recycling. The success of the deposit-refund system for plastic bottles is to some extent due to the PET bottles being a closed-loop system where there is a high value of recycling. In some countries (e.g., Indonesia and South Africa), private companies offer direct payments for returning empty plastic bottles and bags (McIlgorm et al., 2011; Nahman and Godfrey, 2010). Similar incentives have worked in Australia and the U.S.

(Schuyler et al., 2018; Vince and Hardesty, 2017).

An extended producer responsibility instrument creates incentives/a responsibility to provide recycling facilities (e.g., curbside collection) and collection centers; there is evidence that recycling rates decrease as the time and transportation costs of accessing recycling locations increase (Bell et al., 2010). Dahlén et al. (2007) find that the provision of curbside collection of recycled materials promotes separation of metal, plastic, and paper packaging for recycling.

3.3. Regulation

3.3.1. Targeting the plastic industry

To date there is no existing international framework that explicitly addresses plastic pollution due to industrial spills. Most countries have laws to protect the environment from industrial pollution, and firms are required to have environmental permits to operate. These permits typically include provisions for the management of waste, bans on the production of certain plastic materials and products, and incentives to adopt better recycling practices. Also, there is a push toward a chemical “simplification” of plastics in order to increase the recyclability of materials, for example by using fewer polymers and chemical additives. In developing countries, national legal frameworks generally do not regulate pellet spills from the industry. Developed countries have legislation regulating the production, transport, and usage of pellets. For example, the EU has implemented the Packaging Directive (Directive 2008/98/EC, 2008), REACH (Regulation (EC) No 1907/2006), and the Industrial Emissions Directive (Directive 2008/98/EC) to this end.

3.3.2. Targeting plastic consumption

Regulating the consumer market with, e.g., bans is a powerful tool to reduce consumption of certain plastic products, but typically at a non-negligible social cost. One of the most classic examples is the prohibition of the use of plastic bags, with a complete ban on single-use plastic bags being implemented in China, Mauritius, Rwanda, and Kenya (He, 2012; Kish, 2018; Schnurr et al., 2018). Other countries, such as Australia and Senegal, banned light plastic bags thinner than 50 microns (Schnurr et al., 2018). Zhu (2011) indicates that the plastic bag ban reduced the use of plastic bags in China by two thirds, but the effect is heterogeneous, with limited results in wholesale, farmers markets, and the informal sector. Municipal ordinances in the form of both prohibition of single-use plastic bags and changes in their makeup are the most prevalent actions to reduce the use of plastic bags in the U.S. (Wagner, 2017). Although much attention has been placed on regulating plastic bags, efforts are now geared toward reducing plastic straws, plastic cutlery, and polystyrene items such as cups and microbeads (Schnurr et al., 2018).

The effectiveness of plastic bans has been questioned in some contexts, e.g. the ban on the use of plastic bags in marketplaces in India has had little impact, possibly due to a widespread lack of enforcement (Gupta, 2011).

3.3.3. Targeting the disposal of plastics

A regulation targeting plastic waste should be designed taking into consideration the risk of creating illegal dumping or of turning a dangerous residual into an unobservable one. Regulations should target easily observable agents. Landfill bans have been implemented across EU countries, but this inferior waste disposal method is still ubiquitous in developing countries. Landfill bans are expected to reduce marine plastic litter by reducing the leakage originating from landfills (Scharff, 2014).

Recycling laws often target non-hazardous plastic waste. These laws are aimed at establishing institutional mechanisms to facilitate or incentivize waste beneficiation. Recycling laws exhibit a great deal of heterogeneity in terms of type and stringency. Evidence suggests that while the less stringent ones (i.e., announced recycling goals) perform very poorly, the most stringent regimes (i.e., mandatory recycling laws)

have almost doubled recycling rates in the U.S. (Bell et al., 2010).

3.4. Behavioral instruments

Material payoffs are not the only driver of people's behavior. Other important factors include social preferences, social norms, social contexts, and people's cognitive limitations (see e.g. Akerlof and Kranton, 2000; Andreoni, 1990; Thaler and Sunstein, 2009). This suggests several ways for policymakers to influence the production, consumption, and disposal stages of plastics. We distinguish between three broad categories of behavioral interventions: *information provision*, *pure nudges*, and *moral nudges* (Carlsson et al., 2020). Information provision can be used to change people's behavior when there is imperfect information. For example, individuals might care about the environmental impact of their consumption but have limited information about it. By providing information, individuals change. Pure nudges rest on the assumption that people are bounded rational and inattentive, use decision heuristics, or have limited self-control. Under these circumstances, individual behavior can be affected by changes in the decision environment. Moral nudges rest on the assumption that people have social preference and in particular that they care about their behavior in relation to what others do. By providing information about their own and others' behavior, individuals might change their ways. Often both descriptive norms (what is commonly done) and injunctive norms (what is commonly approved or disapproved of) are used in combination. All three types of behavioral instruments have been applied in areas focusing on consumers' environmentally friendly behavior, including information provision (Jessee and Rapson, 2014), design of default options (Ebeling and Lotz, 2015; Egebark and Ekström, 2016), salience of information (Kurz, 2018; Tiefenbeck et al., 2016) and norms in relation to resource use (Allcott, 2011; Ferraro et al., 2011), littering (Cialdini et al., 1990), towel re-use (Goldstein et al., 2008), and food waste (Kallbekken and Sælen, 2013).

3.4.1. Targeting the plastic industry

The main behavioral instrument when it comes to firm behavior is the provision of information to both firms and consumers. There could be a direct effect on firms if they have intrinsic motivation to act in an environmentally friendly manner. The literature on corporate social responsibility suggests several motives for why firms behave in this way, including motivation and attraction of employees (Nyborg et al., 2016; Redford et al., 1997). The other effect of information on environmental performance is that the customers could change their behavior as well and put pressure on firms to improve; this rests on the assumption that customers do care about the environmental performance of firms.

3.4.2. Targeting plastic consumption

Based on the literature on consumption and behavioral policies, it is relatively straightforward to design policies that could affect plastic consumption. However, very few approaches have been implemented and evaluated. We will, therefore, give some suggestions here. 1) *Default*: The default effect refers to the tendency of people to stick with an alternative already chosen by someone else, even when the cost of making an active choice is minimal (Johnson and Goldstein, 2003). Today, consumers are often presented with a "plastics" default, with the most prominent examples being plastic bags and single-use plastics. In such settings, providing a default that involves either no plastics or a substitute to plastics could have a substantial effect on behavior. 2) *Salience*: If people are inattentive to some factors of a decision problem, they will make a different decision than if they were paying attention (see e.g. Allcott, 2011; Chetty et al., 2014). By affecting the salience of certain aspects of the decision, behavior can, therefore, be affected. The best example of this is different types of labeling. A label can have many different roles, including a purely informational role. It is likely that labels also affect the salience of certain characteristics of the product,

and they can have moral values and implications (Carlsson et al., 2020). 3) *Explicit use of social norms*: De Groot et al. (2013) displayed signs with normative messages in a supermarket. These messages varied, but they all aimed to reduce the use of plastic bags and increase the use of reusable bags. One message was "Shoppers in this store believe that re-using shopping bags is a worthwhile way to help the environment. We thank you for helping the environment by continuing to re-use your bags." The reduction in the number of bags was around 30%.

There is also a strand of literature analyzing the combined effects of behavioral and economic policies. As an illustration, there is evidence that the combination of charges for plastic bags and public through information campaigns produced significant and long-lasting reductions in consumption in both Ireland and Argentina (Convery et al., 2007; Jakovcevic et al., 2014), compared with countries such as India and Taiwan, where charges were introduced alone.

Provision of environmental education is another possible way to reduce future consumption. Effects have been found on teachers' and students' knowledge, perceptions, and self-reported behavior in relation to solid waste in general and marine plastic pollution in particular (Hartley et al., 2018, 2015; Hoang and Kato, 2016).

3.4.3. Targeting the disposal of plastics

The literature on behavioral instruments applied to the disposal of waste in general and plastics in particular has mainly focused on the role of behavioral motivations and behavior, and how these are affected by things such as education, information campaigns, and moral nudges. Overall, this literature suggests a stylized fact: while normative behavior is a good predictor of recycling (see, e.g., Barr, 2007; Abbott et al., 2013; Alpizar and Gsottbauer, 2015; Hage et al., 2009; Mahmud and Osman, 2010; Viscusi et al., 2011), personal pro-environmental messages in absence of appeal to norm-based behavior have no effect on recycling (Chong et al., 2013; Xu et al., 2018; Young et al., 2017). Evidence has also shown that while social norms incentivize temporary changes in recycling behavior (Abbott et al., 2013), personal norms generate more persistent changes in behavior (Huber et al., 2018; Viscusi et al., 2011).

There are also studies analyzing the effect of economic incentives coupled with behavioral interventions. For instance, direct payments accompanied with door-to-door information provision have been found to be highly effective in promoting residential waste separation (Xu et al., 2018). Similarly, there is evidence that face-to-face information provision facilitates the adoption of recycling facilities compared with information through bills and municipal websites (Willman, 2015).

3.5. The need for comprehensive policies

An important aspect of plastic pollution is the complexity of the problem. First, a combination of policy instruments may be required in order to induce behavioral changes at one point in the pathway. For example, when trying to encourage waste sorting and recycling, informational and behavioral instruments are complementary to the use of incentive-based policy instruments (Kirakozian, 2016). Second, the potential link between the different parts of the impact pathway of plastics means that policy changes at one entry point could have implications far beyond the original intention. Hence, a major concern is that policy changes at one point may divert the flow of plastics to a path of higher leakage risk. One particular example is the unit-pricing system of waste. Taxes or fees on household waste can result in increased illegal disposal (Fullerton and Kinnaman, 1995, 1994; Linderhof et al., 2001). Given that the leakage risk of illegal dumping is much higher than that of legal disposal, even a small increase in illegal dumping could be counterproductive. With several policy objectives, such as reducing plastic waste, increasing recycling, and reducing illegal disposal, it is highly unlikely, or even impossible, to expect one policy instrument to be sufficient (Fullerton and Wu, 1998; Walls, 2013). Instead, a combination of instruments will be needed, e.g., a tax on sales

Table 1
Application of the decision tree to identify policy goals in developing countries.

| | Production | | Consumption | Disposal | | | |
|------------------|--|--|---|--|---------------------------------|--------------------------------------|---------------------------------------|
| | Balance of trade for the plastic industry* | Share of micro-enterprises in the plastic industry (%) | Plastic consumption per capita (kg/person/day) ^a | Share of plastic inadequately managed (%) ^a | Share of wastewater treated (%) | Share of waste collected legally (%) | Share of plastic that is recycled (%) |
| Chile | Deficit | 87 ⁿ | 0.12 | 7 | 99.8 ^d | 96.49 ^d | 1.7 ^d |
| China | Surplus | 98 ^o | 0.12 | 74 | 93.5 ^r | 62 ^q | 23 ^p |
| Costa Rica | Deficit | 80 ^t | 0.26 | 16 | 11.7 ^b | 58.3 ^e | 1.3 ^e |
| India | Surplus | 75 ^h | 0.01 | 85 | 22 ^s | 60 ⁸ | 47 ^f |
| South Africa | Deficit | 75 | 0.24 | 54 | 57 ^b | 64 ^c | 43.7 ^c |
| Tanzania | Deficit | n.a. | 0.023 | 84 | n.a. | 15.6 | n.a |
| Vietnam | Deficit | 80 ^m | 0.1 | 73 | 11 ⁱ | 85 ^j | 1.1 ⁱ |
| World average | | | 0.20 | 36 | 26 | 64 ^j | 19.5 ^a |
| Top 10 countries | | | 0.16 | 0.85 | 87.5 ^k | 97 ^l | 46.3 |

Sources: ^aJambeck et al. (2015); UNdata (2018) ^cPlastics South Africa (2017), ^d(SUBDERE, 2018; Tello Espinoza et al., 2010), ^e(MS, 2016), ^fBFP (2011), ^gChalmin and Gaillochet (2009), ^hFICCI (2017), ⁱMONRE (2018), ^jLower-middle income countries average 64% (Kaza et al., 2018), ^kOECD (2019), ^lKaza et al. (2018), ^mIVI (2019), ⁿSii (2016), ^oNBS (2018), ^pNDRC (2014), ^qGuojun (2015), ^rMinistry of Environmental Protection of the People's Republic of China (2017), ^sCSE (2014), ^tCalderón Cabrera et al. (2011).

* Country data for 2018. Trade Balance (TB) = Total Value of Exports – Total Value of Imports; surplus if TB > 0; deficit if TB < 0.

of products with an environmental impact together with subsidies for recyclable designs and a deposit-refund scheme.

Finally, while we in this paper focus on policy instruments at the local level, the international trade of plastic products and plastic waste endow local policy changes with global implications. A more restrictive policy enacted in one country could redirect the plastics flow to countries with looser regulations and thus a higher risk of leakage. A landfill ban could reduce local leakage of plastic waste by increasing the incentives to reduce and recycle plastic waste, but it also encourages exporting waste to less regulated regions or countries. Similarly, a ban on single-use plastics may only redirect the plastic consumption to regions without such bans. The transportation process and the final disposal of plastic waste in a less regulated environment could increase the total leakage into the environment. Hence, we need a comprehensive approach that considers global implications when designing national policies.

3.6. The role of technological innovation

Technological progress plays an essential role in reducing plastic pollution. Innovation can change the amount and types of plastics produced but also the way plastics are disposed of. Although research and development can be supported, investment in it is not a policy instrument in itself, but rather the result of a properly designed mix of policies. For example, a tax on single-use plastics, coupled with changes in consumer preferences and information campaigns, can spur a flow of investment in finding suitable alternatives.

The plastic industry is under pressure to produce more environmentally friendly substitutes for conventional plastics (Shah et al., 2008). For instance, studies that reviewed environmentally friendly alternatives have looked at things such as barrier coatings (Lange and Wyser, 2003), biodegradable plastics, and compostable plastics (Song et al., 2009), bioplastic (Stevens, 2003) and biodegradable polymers for food packaging (Siracusa et al., 2008). A key lesson from this literature is that technological innovations should be proven to be viable solutions before they reach the market as they could otherwise delay a behavioral shift away from current patterns of consumption. The current debate on whether biodegradable plastics or polymers are genuinely beneficial for the environment and practically enforceable in the developing world is a good example. The use of biodegradable plastics is gaining ground before the debate is settled, risking a delay in shifting behavior away from plastics.

3.7. The role of voluntary initiatives

Our focus has been on instruments that could be implemented by a policymaker. There could also be voluntary actions taken by consumer groups and firms. These voluntary actions could take many forms, and we will discuss a few below. But first, we wish to stress a few things. First, voluntary actions could be implemented in anticipation of upcoming government regulations, in an effort to reduce support for such policies. Second, voluntary actions will in most cases not be enough to address the problem. The fact that they are voluntary means that some actors might be tempted to continue with business-as-usual and still benefit from the voluntary effort of others. In the long term, this free-riding could erode the pro-environmental behavior of all.

Organized pressure groups, changing consumer preferences, social and environmental reputation, and preemptive change in anticipation of stringent regulation are all good reasons for firms to act pro-environmentally. Individual firms could also be intrinsically motivated to make organizational, operational, and technological changes to reduce the use of pellets, and motivating their employees to help to improve the companies' environmental performance (Redford et al., 1997). The results should also increase employees' commitment to their respective companies.

4. Applying the policy toolbox to the reality of individual countries

The first step in designing suitable policy tools is identifying the main problems. Table 1 outlines the indicators suggested in Fig. 2 for eight developing countries used as examples. Both the average value of each indicator for the top 10 countries² according to the Environmental Performance Index (Wendling et al., 2018) and the world average are also provided.

4.1. Chile

Chile is the best performing country with outstanding levels of waste collection and waste management. The local production of plastics is small, although the high share of microenterprises could be a concern since they might be less efficient. The per-capita consumption of plastics is low compared with the benchmark. The focus of the

² Switzerland, France, Denmark, Malta, Sweden, the United Kingdom, Luxemburg, Austria, Ireland, and Finland.

Chilean authorities should be on waste beneficiation, given that only 1.7% of the plastics consumed are recycled. Policies to increase recycling and the domestic demand for recycled plastic should be implemented. The plastic industry should be targeted with an EPR policy. A deposit-refund scheme for plastic bottles and containers would increase the value of plastic waste. Behavioral interventions in the form of information and education, and with a focus on people's environmental values and norms should help to incentivize recycling.

4.2. China

China is one of the world's largest producers of plastics and one of the most significant contributors to marine plastic pollution (Jambeck et al., 2015; Lebreton and Andrady, 2019). China's plastic production depends mainly on microenterprises. On the other hand, China's per-capita consumption of plastic is low compared with the world average. China's contribution to marine plastic pollution is caused by its high share of mismanaged waste and a low recycling rate (NDRC, 2014). In the short run, the focus should be on improving landfill technology, recycling, and waste beneficiation. The first goal requires government investments to migrate from inefficient dumpsites to modern technologies, backed by regulations. The promotion of recycling, particularly of domestically produced plastics, requires not only behavioral change but also improvements in the regulation of the plastic industry, which now produces plastics with low recycling value due to the high use of surfactant and additives (Velis, 2014).

4.3. Costa Rica

Costa Rica has three critical indicators: high levels of plastic consumption per capita, low levels of wastewater treatment, and low levels of plastic beneficiation. In order to reduce the consumption of plastics, the government has already launched an information strategy to replace single-use plastics with renewable and compostable alternatives (MS et al., 2016). A ban on single-use plastics is being considered as a policy option, but Costa Rican authorities could use the policy design framework in this paper to broaden the availability of policy options. Wastewater treatment plants capable of capturing microplastics require direct investments by the government, which already faces serious challenges with the country's standard facilities. Still, even a standard facility is better than none. Finally, policymakers should attempt to increase the demand for locally recyclable plastics by implementing a mix of behavioral, market-based, and regulatory instruments that will increase the recycling of plastics and reduce plastic consumption. A deposit-refund scheme for plastic bottles and containers should be implemented.

4.4. India

The share of waste collected legally in India is around 60%, but this does not translate into managed waste, as the waste is disposed of in dumps or open in uncontrolled landfills where it is not fully contained: 85% of the waste is inadequately managed. In addition, 78% of the wastewater goes untreated to the rivers and from there into the ocean. India's policy target is clearly and unequivocally locked on improved landfill technology and modern wastewater treatment. India's high level of recycling is certainly good, but there are concerns about leakages during collection and transportation, as the recycling sector is mainly informal and does not adhere to government regulations. A deposit refund scheme could increase the value of plastic containers, helping the migration to the formal sector of currently informal operators.

4.5. South Africa

In 2015, South Africans consumed approximately 1.78 million tons

of plastics (Plastics South Africa, 2018). Around 44% of that amount is eventually recycled, although a large share is sourced from landfills at a high cost. Landfill material is generally of poor quality, contaminated, and therefore expensive to recycle (Plastics South Africa, 2017). Moreover, only 64% of households have access to formal waste management (Plastics South Africa, 2017), and many deposit their litter informally or illegally.

In terms of policy design, South Africa should attempt to increase the value of plastic waste, not the least by promoting that actors in the informal sector to become formal. At the industry level, EPR schemes represent an opportunity to assign duties to retail companies for the plastic materials at the end of the product lifecycle. At the consumption stage, deposit-refund schemes for plastic containers should reduce the amount of plastic for recycling that is sourced at the landfill. Finally, the per-capita consumption of plastics in South Africa is much higher than our benchmark, and the largest share of it originates from packaging (Plastics South Africa, 2018). Regulatory changes might go a long way in reducing the amount of discarded plastic packaging material.

4.6. Tanzania

Tanzania's plastic originates from land-based activities and is mostly attributable to mismanaged solid waste management, especially in unplanned urban settlements (UNEP, 2009). Only 16% is collected legally, and 84% of all plastics are inadequately managed and disposed of informally in various ways, such as by burning and roadside dumping (NBS, 2017). Urban areas produce most of the waste. For example, in Dar es Salaam, solid waste generation has been steadily increasing. In 1998, less than 2,000 tons per day was produced, and this increased to more than 4,600 tons per day by 2017, 75% of which was produced by households (NBS, 2017). Most of the urban waste is dumped at Pugu Kinyamwezi, the only dumpsite in Dar es Salaam (NBS, 2017). Although initially designed as a proper landfill, Pugu Kinyamwezi has become a basic dumpsite with severe leakages.

The case of Tanzania is rather simple from a policy perspective. The focus should be on increasing the legal disposal of solid waste. Although this applies to all solid waste, a proper separation of plastic waste from organic waste would make landfills more viable. The separation of waste at the household level through behavioral instruments could substantially reduce the cost of properly managing both types of waste.

4.7. Vietnam

Vietnam is infamous for the amounts of plastic waste in its vast riparian network (Schmidt et al., 2017), especially during the rainy and flood seasons (Lebreton et al., 2018). Agriculture and aquaculture activities generate a large volume of plastic waste (Blanco et al., 2018). As for urban river systems, waste comes from municipalities, causing environmental problems and transportation of waste to the ocean. For instance, a recent study found a high density of both micro- and macro plastics in the Sai Gon River in Ho Chi Minh City (Verma et al., 2016). Unlike some other countries, policies against single-use plastic products are weak (UNEP, 2018). Most waste is not sorted at the source. Only some valued plastics are collected and recycled informally and most waste (e.g., plastic bags and straws) is simply dumped into the environment. About 46% of all solid waste comes from urban municipalities, 17% is discharged from industrial zones, and the rest from rural areas, the medical sectors, and trade villages. The waste collection rate is about 85%.

The waste management infrastructure is poor as transportation stations and landfills are insufficient and treatment technologies outdated (Verma et al., 2016). As a result, 73% of all plastic waste is inadequately managed. This should be the target of the decision-maker.

5. Conclusions

We present an impact pathway framework that facilitates the identification of critical policy entry points for a decision-maker interested in reducing the flow of plastic waste into the sea. We extend the previous literature on policy instruments to curb marine plastic pollution by providing a comprehensive review of policies, including insights from behavioral economics. Most importantly, we discuss the use of this policy toolbox at different levels or branches of the impact pathway, and suggest critical thresholds for policy-action in each. The result is a decision support tool for policymakers that is both country- and problem-specific.

The impact pathway framework also allows for the identification of interactions between policies, interactions that could be either positive or negative. A positive interaction occurs when a policy in one domain, e.g., using extended post-consumption producer responsibility to make companies more responsible for the plastic content of their products, interacts positively with a policy in another domain, e.g., increased recycling. A negative interaction occurs when policies actually conflict with each other, e.g., if improved landfill technologies bring higher prices per kilogram of waste and an increase in illegal dumping of waste.

In addition, the fact that waste is created, packaged, and disposed of privately by households means that information is highly asymmetric. Policymakers should attempt to design comprehensive policies that are compatible with this type of information and attentive to the interconnections as described by the impact pathway.

Finally, although marine plastic debris is ultimately a global problem, it originates in local decisions in countries that lack proper policies and institutions. Floating plastic debris might be the same irrespective of its origin, but the reason for this differs by location. Policy design needs to be attentive to those differences. In this paper, we propose a decision support tool based on a set of simple indicators that can easily guide the decision-maker to the crux of the problem. Although the selection of indicators can be expanded on and improved, the key rationale is that decision-makers need quick ways to identify the problem and then a menu of potential policy solutions. Too frequently, decision-makers invest time, effort, and political capital promoting good solutions that do not get to the core of the problem.

This paper provides a comprehensive review of policy instruments and in doing so reveals some research gaps. First, the literature focuses on understanding the behavior of individuals/households while little attention is devoted to understanding the behavior of a broader group of consumers such as hospitals, schools, and universities. Second, although there is vast evidence regarding the importance of personal norms for individual behavior, most behavioral interventions rely on one-shot information provision while long-run interventions in the form of environmental education are rather scarce. Finally, although marine plastic pollution has both land- and marine-based sources, studies of the effectiveness of policy instruments targeting actors in the latter category (e.g., small fishing and aquaculture companies, fishing communities, and tourists) are absent.

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F. Alpizar: Conceptualization, Methodology, Supervision, Investigation, Writing - original draft. **F. Carlsson:** Conceptualization, Methodology, Supervision, Writing - review & editing. **G. Lanza:** Writing - original draft, Investigation, Visualization, Project administration. **B. Carney:** Writing - review & editing. **R.C. Daniels:** Writing - review & editing, Investigation. **M. Jaime:** Writing - review & editing. **T. Ho:** Writing - review & editing. **Z. Nie:** Writing - review & editing. **C. Salazar:** Writing - review & editing. **B. Tibesigwa:** Writing - review & editing. **S. Wahdera:** Writing - review & editing.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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