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Beenish Amir

Innovation and Technology Centre
Lahore School of Economics

Innovation and Technology Centre (ITC)

Dr. Azam Chaudhry
Professor, Dean & Head of Department (Economics)
Pro-Rector
Co-Director

Dr. Theresa Chaudhry
Professor (Economics)
Co-Director

Innovation and Technology Centre,
The Lahore School of Economics,
Intersection of Main Boulevard, Burki Road,
Phase VI, DHA, Lahore 53200, Pakistan
Tel: +92-(0)42-3656-0969
URL: https://itc.lahoreschool.edu.pk
Email: ayeshakh@lahoreschool.edu.pk

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Beenish Amir
Teaching and Research Fellow
Innovation and Technology Centre,
Lahore School of Economics, Pakistan.
beenishamir8@gmail.com
ORCID ID: 0000-0002-6803-9214

Abstract: *This paper has looked at the response of plastic manufacturers and retailers after the introduction of Pakistan environment protection Act of 2019. This paper conducts analysis of the behavior of government, manufacturers and retailers using evolutionary game theory model. This model was used to test for hypothesis related to various characteristics associated with the three players. Main variables selected for this purpose include probability of adoption of business process innovation, probability of monitoring, income manufacturers and retailer can expect from innovation and costs associated with non-compliance of regulations. Furthermore, we conducted simulation analysis to look at the stability of equilibrium strategies. Additionally, we conducted a small survey in Lahore and Islamabad on plastic bag manufacturers and retailers to find empirical support for our research. The results showed that environmental regulation can be helpful if incentive-based approach is used by the government. Subsidies and tax incentives should be given to manufacturers and retailers for adopting business process innovation and using environment friendly bags.*

Keywords: Pakistan Environment Protection Act of 2019; Government, Manufacturers, and Retailers; Dynamic Evolutionary Game Model; Business Process Innovation.

JEL Classification: Q50

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1. Introduction

Globally, single-use plastic bags have been popularly used since the past eighty years but the problems they have created for the environment might take centuries to correct. Plastic bags are commonly used by developing countries because of their durability, water resistance, weight, and easy accessibility (Bumbudsanpharoke & Ko, 2022). It is a common practice in developing countries to use plastic bags to transport water and milk in many areas as well as to hold fruits and vegetables (Kumar et al., 2022). Even though, plastic bags have many significant uses in our daily routine however, their usage has strong repercussions for marine life, human health, and atmosphere. Marine life is threatened by extensive use of plastic bags because plastic debris usually end up in the sea (Høiberg et al., 2022). Moreover, when plastic bags are ingested by marine animals then it can reduce their stomach capacity which can cause reduction in nutritional intake and may even cause death (Watt et al., 2021). Furthermore, if humans consume marine animals which were exposed to plastic debris, then it can have detrimental effect on human life as well (Davison et al., 2021). As plastic bags are non-biodegradable, they keep on piling up and can become breeding ground for malaria which is damaging for human health (Aligbe, 2021). People sometimes try to burn plastic bags to get rid of mounds of waste, this causes emission of greenhouse gases which is harmful for the atmosphere (Badola & Chauhan, 2022). Moreover, improper waste disposal of plastic bags means that they usually end up clogging sewers which can even cause floods to occur (Genon et al., 2022). Scientists say that if plastic problem is ignored then global plastic production might increase from 450 million tonnes to 900 million tonnes in 2045 (Gkoutselis et al., 2021).

To cope with the rising problem of plastic pollution globally, United Nations (UN) launched its sustainable development goals in 2015, since then many countries have tried to incorporate these goals in their policy making process in order to deal with environmental issues (Lal et al.,

2021; Salvo et al., 2021). A lot of work is being done specifically to follow Goal 14, which says *"Conserve and sustainably use the oceans, seas and marine resources for sustainable development."* Precisely, section 14.1 says, *"By 2025, prevent and significantly reduce marine pollution of all kinds, in particular from land-based activities, including marine debris and nutrient pollution"*. After this, Paris agreement and Stockholm convention have also focused on plastic reduction (Barrowclough & Birkbeck, 2022;Simon et al., 2021). China has also introduced environmental policies which focus on reduction in carbon emissions through green subsidies (G. Li et al., 2022; Yang et al., 2021; X. Yu & Wang, 2021).

In order to achieve sustainable development goals, single-use plastic bags have been subjected to many types of regulations by policy makers around the world (Borg et al., 2022). Some countries have enforced bans and taxes on plastic bags production while other countries have encouraged people to voluntarily give up using plastic carrier bags by creating awareness among consumers and retailers (Muposhi et al., 2022). Developed countries have mostly imposed pricing strategies compared to outright bans because they do not face waste disposal issues compared to developing countries (Bharadwaj et al., 2021). Many African countries have imposed strict ban on production, sale, and usage of plastic bags (Behuria, 2021).

Looking from the South Asian perspective, Pakistan is said to have the highest rate of improper plastic bags waste management (Akmal & Jamil, 2021). United Nations Development Program (UNDP) reports regarding Pakistan show that around 3.3 million tonnes of plastic is wasted in Pakistan annually (S. Ali, Ahmed et al., 2022). Furthermore, the report says that if all plastic waste is dumped collectively then it might exceed the height of the tallest mountain in the world. Plastic is used in multiple areas of life, but the threat posed by single-use plastic bags is the greatest (Y. Chen et al.,2021). In 2019, Pakistan became the 128th country in the world to impose a ban on use, sale and distribution of single-use, non-biodegradable plastic bags (Y. Ali & Sara, 2021). This ban was initially imposed in Islamabad by Pakistan Environmental Protection Agency (EPA) but, eventually it extended to other parts of Pakistan as well. Under this ban, a fine was imposed from PKR 10,000 till PKR 500,000 for violation of regulation. As discussed earlier, Pakistan is not the first country to impose environmental regulations to control production, usage, and distribution of plastic bags. However, it is interesting to see whether a

developing nation whose plastic bag manufacturing industry is the fifth largest employer in Pakistan (S. Ali et al., 2022) can work under global pressure to reduce its plastic bags production and consumption successfully and adopt sustainable business production.

Studies which have been previously conducted show that there is a chance that incorporating environmental regulations in business processes can make production costlier for firms which can cause them to lose their competitive advantage in the market (L. Liu et al., 2021). Many researchers disagree with these results; they argue that regulations which focus on sustainable development can encourage firms to follow business process innovation which encourage efficiency and lower operational costs (Khan et al., 2021). One main advocate of the link between environmental regulations and increased efficiency of businesses is Michael Porter who came up with the Porter hypothesis (Porter, 1991). According to this hypothesis, successful implementation of environmental regulations can encourage firms to adopt business process innovation which can improve their market competitiveness (M. Wang et al., 2022). If regulations are not designed properly or implemented properly then firms have no incentive to alter their business processes (Kwoka & Valletti, 2021). Moreover, firms need to examine the conditions in which they are operating under, before they decide to adopt sustainable business practices (Barros et al., 2021). Porter hypothesis does not state that environmental regulations will always cause businesses to innovate; the role of consumers and retailers is also important (C. Li et al., 2022).

By looking at the global supply chain process, we can see that consumers and retailers are also influenced by environmental regulations imposed by governments. There is a two-way relationship between customers and businesses, both stakeholders can pressurize each other to adopt practices which are sustainable (Sanchez-Planelles et al., 2022; Zameer et al.,2021). In today's modern world customers are more aware of environmental degradation and they demand ecologically sustainable production and retailers are bound to provide them with eco-friendly products. If firms are successfully able to cater to customers' needs their market share can increase (Krafft et al., 2021). If environmental regulations are well designed, then firms are forced to recognize the externalities that their actions can cause (Ruan & Liu, 2021). If businesses are successfully able to incorporate compliance costs in such a manner that their profitability increases, then it is a win-win situation for both firms and policy makers (P. Yu et al., 2022). This occurs because when

sustainable processes will be adopted there will be low levels of carbon emissions which will be good for the environment, there is less wastage of non-renewable resources, and as more people demand sustainable products it will lead to long term structural adjustment of the industry (Nakhli et al., 2022).

Taking guidance from existing theoretical background provided by the Porter hypothesis we have looked at the process by which environmental regulations can drive adoption of business process innovation as well as how retailers respond to these regulations. For this purpose, we have constructed a three-player evolutionary game model and analyzed strategic behavior of all the parties involved. For this study we have looked at the Pakistan Environment Protection Act of 2019 which imposed a ban on production, sale, and usage of single-use plastic bags. There are studies present for Pakistan which have looked at the relationship between environmental laws and firm responses by using traditional game theory models as well as qualitative research (S. Ali et al., 2022; Zaheer et al.,2021). However, these studies have not looked at the perspective of retailer's response to government regulations, that is, strategies of retailers are mostly ignored in existing studies due to which we feel the need to include them in our study (S. Ali et al., 2022; Mishra & Yadav, 2021; Q. Wang et al.,2021). The existing literature shows there is a gap due to which further investigation is needed to analyze their behavior.

In our study we have looked at government, firms, and retailers in different scenarios. Our particular focus is on six different scenarios. Government (regulations), firms, and retailers have multiple strategies which they can adopt. While developing the evolutionary game model, initially the expenses and revenue of each player are assumed and strategies are decided, (Fan et al., 2021) like for firm's costs can be related to investment in sustainable technology, while for government the cost can be of monitoring and supervision. For retailers the cost can be of spending more money on purchasing sustainable eco-friendly bags. After this the payoff matrix is designed and replicator equation is built. This equation is solved after including all proposed parameters of the game model and then the stable strategy is identified. Once this step is completed then a simulation analysis is carried out to clearly present the findings.

This study contributes significantly to existing literature present on relation between environmental laws and firm behavior. The key innovation points of this study Firstly, this study is for a developing country like Pakistan in

which there is a dearth of literature available on measures taken for sustainable development. This study provides an in-depth quantitative analysis of the effect of Pakistan environment protection act of 2019 on firms' adoption of business process innovation. The studies which have been previously conducted have either looked at traditional game models or just conducted qualitative analysis using surveys and interviews (S. Ali et al., 2022; Zaheer et al., 2021). Secondly, this paper uses replicator dynamic evolutionary game theory model which is different from traditional game theory because it looks at all players without any stringent assumptions about rationality (Dou et al.,2021; C. Li et al., 2022; Yuan et al., 2022). It allows usage of a framework which is relatable to real world situations, and which is applicable for all the involved players. By using evolutionary game theory, we can holistically look at the relationship between environmental regulation, firm behavior, and retailer responses. Thirdly, the focus of our study is the plastic bags industry of Pakistan because the environment protection act of 2019 directly affects the supply chain of plastic bags, which includes plastic manufacturing firms as well as retailers who keep plastic bags for their consumers. We have not come across any research that has applied evolutionary game model to look at the plastic manufacturing industry of Pakistan or the retailers who use plastic shopping bags (S. Ali et al., 2022; Y. Ali et al.,2021; Haq et al.,2021; Rizwan ahmed & Siddiqui, 2021). Overall, we feel that this research will provide valuable insights on how manufacturers and retailers based in Pakistan react to environmental regulations because Pakistan is a developing country which suffers from low economic growth.

The structure of this paper is as follows. It is divided into 6 sections; section 2 is Literature review which consists of all relevant research regarding environmental regulations and firm behavior. The theoretical background and opposing theories have been extensively discussed in this section. Section 3 consists of methodological framework and model construction; in this we have presented the proposed parameters of the game model as well as the payoff matrix for each player. All assumptions related to each player are also present in this section. In section 4 we have solved the replicator dynamic equation, searched for stable strategy, and carried out simulation analysis. In section 5 we have the analysis and discussion of our model along with policy recommendations. Lastly, in section 6 we have discussed limitations of our model and highlighted areas of future research.

2. Theoretical background and Literature Review

Due to an increase in population as well as growth driven economic policies, plastic pollution has become a serious problem. This issue has attracted much attention from academics and researchers who are trying to find ways of reducing plastic usage. Presently, plastic usage is widespread in the form of water bottles, agricultural produce, plastic straws, food packaging and many other purposes (Varkey et al.,2021).

2.1 Theoretical background

Multiple theories have discussed the relationship between environmental regulations and business process innovation. In 1994 Walley and Whitehead presented a neoclassical theory which claimed that environment related regulations put pressure on firms to adopt measures to reduce pollution which increase their variable costs and put a dent on their profits. Meaning that sustainable business process innovation has a negative effect on business performance. In contrast to this theory (Porter, 1991) considers that technological innovation can be encouraged by environmental regulations, which in effect can reduce costs and improve business performance (Song et al.,2022). Furthermore, Michael Porter introduced the win-win paradox in which he suggested that firms can seize opportunities presented by environmental laws to improve their business performance by switching to business process innovation (C. Li et al., 2022).

Multiple studies have shown results which are consistent with the Porter hypothesis (Akbar et al., 2021). In contrast, there are studies present which found that environmental regulations did not have any significant effect on sustainable business performance (Bhatia, 2021; Rahuma & Fethi, 2022).

The most applicable theory is the resource-based view and stakeholder theory. These theories state that firms can use the resources of the organization to deal with environment related problems, this can help firms to improve their business performance (Gerhart & Feng, 2021). This essentially means that maintaining good relationship with environmentally conscious customers and suppliers has a positive effect on sustainable business performance.

2.2 Influence of environmental regulation imposed by government on firm's adoption of business process innovation

When plastic bags were first introduced, they were treated as semi-public goods because they had limited life and were easily available (O'Brien & Thondhlana, 2019). Due to these characteristics, the problems caused by plastics were ignored for a long time. To control environmental disruptions caused by plastic bag usage, environmental regulations have been put in place (Silva et al., 2020). The effects of these regulations have been under debate by many theorists. Neoclassical theory suggests that environmental regulations should impose costs which are based on marginal cost principle, that is, price charged for plastic alternatives should be equal to the marginal social costs incurred by the manufacturers of complying with these regulations (Hasson, Leiman et al. 2007) .

The most common method of regulating plastic bag usage and distribution is to ban them entirely (Clapp & Swanston, 2009). The reason for its popularity is that there is a defined method of using this policy. The administrative body maps out the target of the ban and ways to enforce the ban (Sivadas et al., 2022). Theoretically, this is very easy to do for the government or environmental regulatory body. The difficulty comes in execution of the ban because many people argue that bans provide only a short-term solution; in the long run black market for plastic bags might increase (Nielsen et al.,2019).

Policies to ban plastic bags started in the late 1990's from India and Bangladesh (Hossain et al.,2021). Later, other countries in Asia as well as Africa adopted similar policies. The strictness of these bans varied from country to country. In Rwanda for example heavy fines were imposed on using plastic bags with up to one year of imprisonment for retailers of plastic bags (Behuria, 2021). In Kenya there were harsher punishments for usage and manufacture of plastic bags (Njuguna, 2018). The reason why Kenya and Rwanda along with a few Asian countries adopt harsh measure to ban plastic bags is because of health issues caused through plastic usage (Adam et al.,2020). These areas have poor waste management systems so, plastic bags just add to existing land pollution (Mihai et al., 2021). In countries where waste management is not an issue, some types of plastic bags are excluded from bans, for example in China, ban is placed on only lightweight plastic bags (Arriagada et al.,2022).

In addition to placing bans on usage of single-use plastic bags, governments should focus on regulations which encourage sustainable business process innovation (Sharpe et al., 2021). Sustainable business process innovation means using technology which can reduce pollution caused by plastic bag manufacturers (Shakeel et al.,2020). Altering business process can result in creation of products which are healthy for the environment.

Firms are adopting sustainable business practices by altering existing technology and creating environmentally sustainable products (Albort-Morant et al.,2018; Awan et al.,2021) because fewer resources are wasted (Ibn-Mohammed et al., 2021; Oláh et al., 2020). This way, firms can reap profits from business process innovation and cover cost of complying with environmental regulations (Asadi et al., 2020; Dong et al.,2022). How firms can achieve sustainable business practices can be determined through the "Smiling Curve" hypothesis (Meng et al.,2022). According to this hypothesis those firms can add most value which have high barriers to entry. Firms can add value by focusing on process innovation in manufacturing. Under the smile curve model, firms rely on technological innovation which can help in reducing energy consumption, improve operational efficiency, reduce variable costs, and constantly add value to production so that sustainable development is achieved (Florida, 1996; Ghisellini et al.,2016). Traditionally, technological innovation was viewed as beneficial for firm only, through reduction in production costs and economies of scale but sustainable business production can benefit the environment, economy, and society (Gupta et al.,2021; Lahti et al.,2018). Whichever type of innovation a firm adopts depends on multiple factors, because the business performance of a firm is not just affected by internal resources; external pressures also have an important role (W. L. Lin et al.,2020). According to a project of the European Union called "Measuring Green Innovation"; features of innovation, market for innovation, environmental regulation, and features of "green innovation" are factors which can affect business performance (Skordoulis et al., 2022).

Studies have shown that environmental regulations which provided subsidies to manufacturers who complied with regulation encouraged business process innovation (J. Liu et al.,2020) (Seman et al., 2019). In contrast to this, (J. Zhang et al., 2020) conducted a study on effect of environmental laws on business process innovation and found that supervision was less effective encouraging environmentally sustainable innovation compared to market-based or voluntary regulation.

F.-W. Chen et al.,(2018) look at the impact of sustainable innovation and environmental regulation on environmentally sustainable growth. This research was based on theory of complete interduality. They applied a Durban spatial model for this purpose by dividing regulation in to three subcategories, namely, administrative, voluntary and market based. Provincial level data was collected from China and results showed that different regional regulations had different effects on environmentally sustainable growth.

2.3 Influence of environmental regulation of government on retailer's adoption of business process innovation

Stakeholder theory says firms can meet the environment related requirements of stakeholders as well as improve business efficiency by adapting to changes in the external environment (Nguyen et al.,2021). This means that maintaining good relationship with environmentally conscious customers and suppliers has a positive effect on sustainable business performance.

Environmental regulations are placed not only on firms but also on users and distributers of single use plastic bags. (Bharadwaj et al., 2021) discuss the case of Nepal where a ban is placed on single-use plastic bags. In their paper they suggest that environmental regulations like complete ban on plastic bag usage presents challenges. If time and effort is not spent on monitoring of plastic bag distribution, then the ban might be ignored by manufacturers and retailers alike. They conducted three rounds of retailer level data for a municipality in Nepal to test their claims and found support as well. Plastic bag usage went down at the beginning of the ban but when likelihood of fine decreased then more retailers were using plastic bags. They concluded that continuous monitoring is required to impose a ban on use of plastic bags.

For a study done on Zimbabwe (Chitotombe & Gukurume, 2014) saw that when a plastic ban was imposed without informing retailers and customers first there was resistance from these two stakeholders. After this ban retailer started charging very high prices for biodegradable bags so that they don't lose out on their profits. When a policy is implemented without involving all stakeholders then policy makers should be prepared to face resistance and high monitoring costs (Howlett & Leong, 2021). Muposhi et al., (2022) reviewed the literature present which recorded effects of plastic bans in various situations. In many countries, retailers

started exploiting customers by charging high prices for plastic bag substitutes. After a plastic ban was introduced in China, many retailers in rural areas ignored it and kept on providing free plastic bags (B. Wang & Li, 2021). Even if a ban is not placed on plastic bags, instead a pricing mechanism is adopted then even retailers might react differently depending on enforcement and monitoring. For some retailers, pricing plastic bags can be a source of income due to which they will have little or no incentive to discourage the sale of plastic bags (Cabrera et al.,2021).

At times big retailers voluntarily decide to reduce their usage of plastic bags as part of their corporate social responsibility objectives. At the World Economic Forum in 2018, many brand owners and retailers agreed to using packaging which is reusable and recyclable. The environment program of the United Nations provides guidelines that businesses can follow for more sustainable and environmentally friendly production (Gonçalves & Silva, 2021).

2.4 Additional contribution to literature

We have looked at different contexts within which governments have imposed environmental regulations and responses of manufacturers and retailers to such policies our contribution to literature is based on three elements. Firstly, our three players; government, manufacturers and retailers are bounded by assumptions of rationality. Secondly, we have looked at the stable strategies of the three players under different scenarios. Lastly, in contrast to most of the literature which has focused on empirical or theoretical analysis, we have placed focus on replicator dynamic evolutionary game model which is a relatively new approach to analyze strategies of different stakeholders. The ban on single-use plastic might be ecologically beneficial but whether it contributes to overall economic growth along with sustainability is still very confusing for researchers.

The key reasons for selecting Pakistan as a model country includes:

i. The Pakistan Environment Protection Act of 2019 was recently introduced and as per our knowledge there is no specific study present in Pakistan which has examined the relationship amongst single-use plastic manufactures, government and retailers.

ii. Many laws are introduced in Pakistan, but few are implemented, through this study we want to see the effectiveness of Pakistan

Environment Protection Act of 2019 in curbing excessive use of single-use plastic bags and encouraging adoption of business process innovation.

iii. Out of all the literature we have looked at, only few studies have used replicator evolutionary game model to incorporate multi stakeholder perspective in their research. Most studies have applied empirical analysis for this purpose (Huang & Lei, 2021; H. Wang et al., 2021; Yao et al.,2021; D. Zhang & Vigne, 2021).

3. Theoretical framework and methodology

To curb with rising pollution plastic, the Environment Protection Agency of Pakistan introduced the Environment Protection Act of 2019. A team has been appointed to monitor and supervise implementation of this act. It is important that plastic manufacturers and retailers comply with this act because of rising levels of environmental degradation. Pakistan offers valuable insight to understand the relationship between environmental regulations and whether firms adopt business process innovation. Similarly, we can also check if retailers are complying with environmental regulations by reducing distribution of single-use plastic bags.

Based on theoretical background provided by Porter hypothesis and smile curve model we can look at the behavior of all three stakeholders. Logically, when government introduces environmental regulations such as Pakistan environment protection act of 2019, then firms should adopt business process innovation to avoid being penalized. Also, retailers should avoid using single-use plastic bags. Still, in some cases firms and retailers can choose to be penalized for non-compliance because the cost of adopting new processes is higher. Similarly, government also has a choice; it can either follow strict regulations by either taxing firms and retailers for engaging in plastic bag manufacture or distribution, or it can provide subsidies to firms and retailers who follow sustainable business practices. Government also has the choice of neglecting any harm done to the environment. Thus, a game model can be constructed to observe each player's behavior under different scenarios.

3.1 Application of conventional game models to assess manufacture's and retailer's response to environmental regulation by government

Many studies are present which have used game theory to understand effect of various environmental regulations. Game theory was first used to study chance of acid pollution in various European regions by Maler (Mäler & De Zeeuw, 1998). He has modeled game theory for around 27 countries and concluded that "unilateral payment" is important for mutual support among countries. (Hottenrott & Rexhäuser, 2015) used game theory models to conclude that if government give tax relief to firms who adopt business process innovation, then more firms will want to innovate. Hafezalkotob (2015) used a Stackelberg model to assess two types of firms and retailers; those who are environmentally friendly and those who are not. The model looked at behaviors under different strategies adopted by the government. Results of this model showed that government attitude towards environment and social responsibility had a large effect on profits earned by retailers and manufacturers under both setups.

W. Wang et al.,(2015) looked at the type of system adopted by the government to control pollution. Higher fines or higher incentive meant lower levels of pollution. (Madani & Rasti-Barzoki, 2017) constructed a game model that revealed that subsidies can have more effect compared to taxes if governments want to encourage firms to adopt business process innovation.

In the case of Pakistan, (S. Ali et al., 2022) applied a game theory model to observe behavior of plastic bag manufacturers in response to environmental regulation imposed by the government. Their game theory analysis showed that a policy to impose fines on production of plastic bags might be productive in the short run but in the long run it is important to create awareness among the consumers of plastic bags about environmental destruction caused by plastic usage.

3.2 Application of evolutionary game theory models to assess manufacturer's and retailer's response to environmental regulation by government

In our proposed model we need to understand how firms and retailers react to pressures from environmental laws, for this reason evolutionary game theory model is more applicable compared to traditional game theory model. Evolutionary game theory models were used to study

natural sciences earlier, but now they are used in studies of other disciplines as well. It is challenging to make strict assumptions about the behavior of firms and governments because of differences in internal and external surroundings. To build a dynamic replicator model it is important to draw lessons from biological techniques and mechanisms and expand traditional game theory models (Grüne-Yanoff, 2011). Biological implications apply to business environment as well, because just as living things constantly evolve to improve themselves and deal with the dynamic environments so do businesses. If firms refuse to change their processes and product with the change in environment, then they cannot hope to survive.

Moreover, to maintain good relations with external stakeholders, firms need to update themselves continuously. (H. Lin et al., 2021) accepted that stakeholders cannot behave rationally in real world situations and therefore used an evolutionary game model to examine the behavior of contractors and manufacturers of construction materials. In their paper, (Zhou et al.,2022) used a dynamic evolutionary game model in which government was the main player which was imposing environmental regulations while firms were altering plastic related behaviors in response to these regulations. Results showed that both rewards and penalties increased likelihood of stakeholders changing their view on plastic usage and manufacture.

Tian et al., (2014) conducted an analysis on the automobile industry of China, in which they looked at three stakeholders, namely, government, manufacturers and consumers. For this purpose, they used evolutionary game model Their results showed that to encourage environmentally sustainable supply chain management, subsidies should be given to manufacturers of automobile to promote "green supply chain management" as compared to consumers. In their paper on impact of environmental regulations, (Long et al.,2021) used evolutionary game theory to construct a three-player model consisting of suppliers, manufacturers, and governments. They looked at the strategies of each player independently as well as jointly.

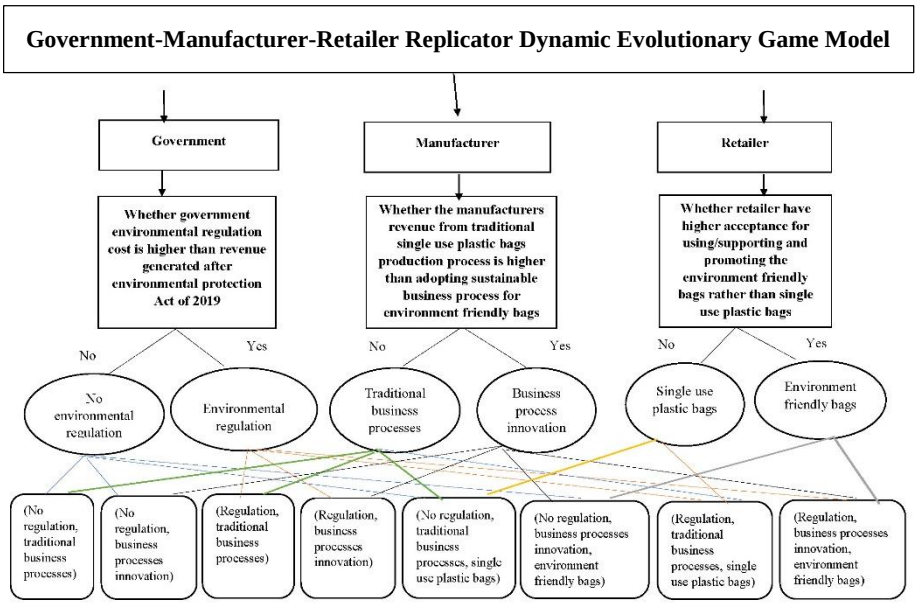
W. Chen & Hu (2018) studied the effect of taxes on carbon emissions and subsidies on carbon reducing products using evolutionary game model, they tried to find the stable strategy that should be adopted by firms. Simulation results showed that carbon taxes on emissions had more effect on manufacturing processes compared to carbon related subsidies. In order

for firms to adopt process innovation or product innovation it is important that they have a dynamic nature as well as flexibility (Bhatia, 2021; Chirumalla, 2021). In today's uncertain world businesses should be able to cater to all kinds of external issues such as strict environmental laws, as well as ecologically concerned customers, this can only happen if businesses are willing to use their resources for business process innovation.

The evolutionary game theory model has been used mostly to evaluate firm's responses to environmental regulations. We have looked at the available literature with much detail and we have not found any study in Pakistan which has used the evolutionary game theory model to study business process innovation in response to environmental regulation

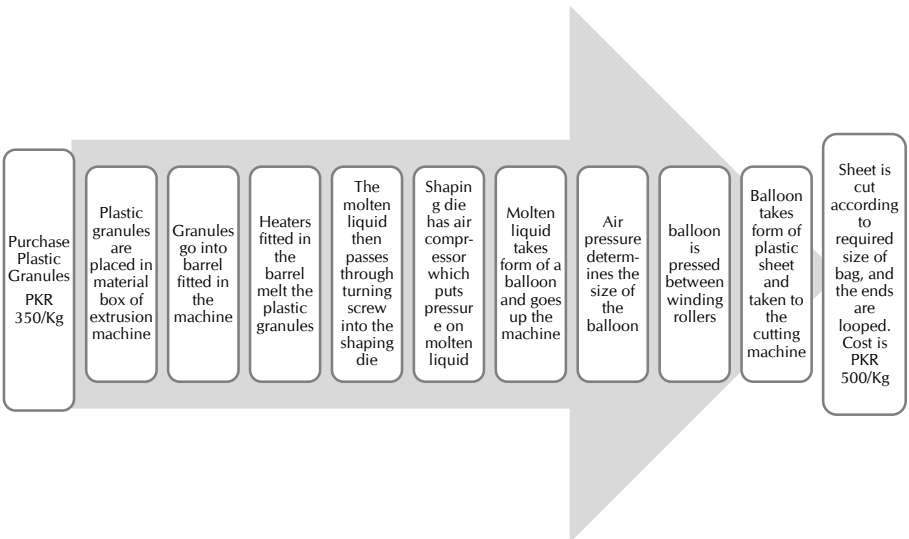
3.3 Structure of the government-manufacturer-retailer replicator dynamic evolutionary game model

Figure 1: Structure of government-manufacturer-retailer replicator dynamic evolutionary game model traditional manufacturing process of single-use plastic bags



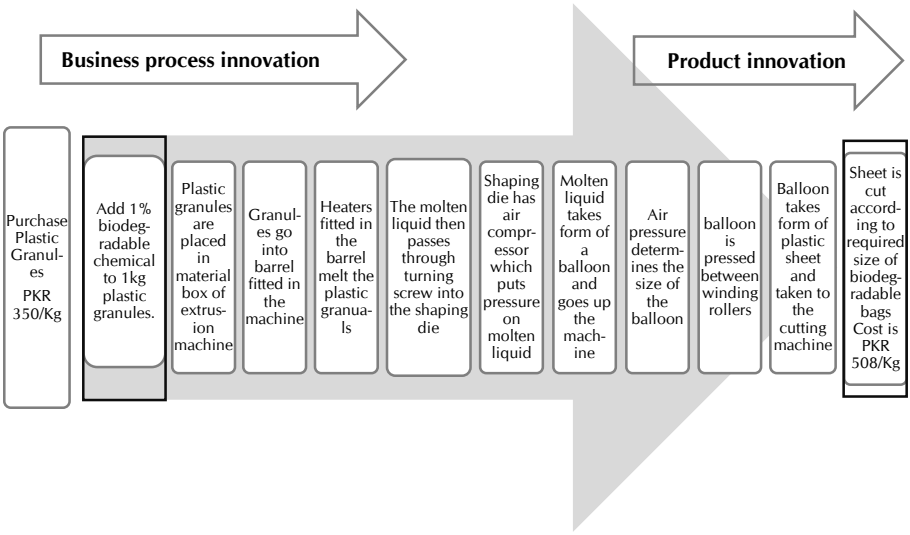
3.3.1 Manufacturer business process innovation vs. Traditional business processes in Pakistan

Figure 2: Traditional manufacturing process of single use plastic bags in Pakistan



Firstly, plastic granules are purchased, then they are transferred in the material box of the extrusion machine. In this machine all the plastic particles are melted and then this molten liquid passes through a pipe and into the die, this die puts pressure on the molten liquid until it takes the shape of a balloon, the more pressure is placed the bigger the balloon becomes. Later, the balloon is passed through rollers which squeeze it until it flattens. The flattened plastic sheet is removed from the extrusion machine and placed in the cutting machine, this machine cuts the plastic sheet according to the required size and at the end loops are made for the plastic bag by wounding up remaining plastic.

Figure 3: Business process innovation in manufacturing of plastic bags in Pakistan



The difference between traditional manufacturing process and business process innovation is the addition of biodegradable chemical in the plastic granules once they are placed in the material box which make the plastic bags biodegradable. Biodegradable chemical costs PKR 10/kg and it makes the process of production more sustainable. 1% biodegradable chemical is added to 1 kg of plastic granules which raises the cost of production by PKR 8/kg.

3.3.2 Survey analysis Manufacturer and retailer response to Pakistan environment protection act of 2019

Table 1: Survey analysis of plastic bag manufacturers in Lahore and Islamabad conducted in May 2022

	Lahore	**Islamabad**
Innovative firms	n = 60	n = 22
Is your firm using biodegradable chemical such as "D2W" in manufacturing process?	Yes (33%)	Yes (35%)
If yes, then for how long have you been using biodegradable chemical?	< 2 years (15%) 2-5 years (13%) > 5 years (5%)	< 2 years (20 %) 2-5 years (10 %) > 5years (5%)
Are you using environment friendly bag making machines?	Yes (10%)	Yes (3%)
Average cost of importing environment friendly bag making machines?	PKR 5 million	PKR 4 million
Is government giving any subsidy or tax incentives for import of environment friendly bag making machines?	No (43%)	No (38%)
Are your costs of manufacturing environment friendly bags higher compared to manufacturing single-use plastic bags?	Yes (57%)	Yes (62%)
Traditional firms	n = 90	n = 28
Are you getting orders for manufacturing single-use plastic bags?	Yes (60%)	Yes (56%)
Average cost of importing single-use plastic bag making machines?	PKR 1.5 million	PKR 1.5 million
Have you ever been fined for manufacturing single-use plastic bags?	Yes (12%) No (48%)	Yes (23 %) No (33 %)
In last one year has any official visited your factory to check what is being manufactured?	No	No
Are you aware if in last 1 year any fine has been imposed on manufacturing of single-use plastic bags?	No	Yes (15%) No (41 %)
Are your costs of manufacturing single-use plastic bags lower compared to manufacturing environment friendly bags?	Yes	Yes

For additional research, we conducted a survey of plastic bag manufacturers and retailers based in Lahore and Islamabad. We visited three industrial estates in Lahore, namely Quaid-e-Azam industrial park, Sundar industrial estate and Farooq industrial estate. Moreover, we looked at plastic bag manufacturers near Islamabad like Neelah Dullah and Rawalpindi area. We surveyed 150 firms in Lahore and 50 firms near Islamabad. First question of our survey was related to business process innovation, through this question we differentiated between innovative firms and traditional firms. There were 60 innovative firms out of 150 in Lahore and 90 traditional firms. In Islamabad there were 22 innovative firms out of 50 and 28 traditional firms. Table 1 shows the division of these firms. Different questions were asked to each category and the answers are expressed in percentage form based on total of each category. As we can see from the table, few firms have altered their manufacturing processes in response to environment protection act. We have added some pictures in Appendix A related to the manufacturing process.

Table 2: Survey analysis of retailers in Lahore and Islamabad conducted in June 2022

	Lahore	**Islamabad**
Survey questions for retailers	**n = 300**	**n = 200**
In last 1 year any official visited to check on bag usage?	Yes (32%) No (68%)	Yes (44 %) No (56%)
In last 1 year any fine on bag distribution?	No	Yes (19%) No (81%)
Any tax incentive offered	No	No
Has cost of bags risen?	Yes	Yes
Are customers willing to pay for environmentally friendly bags?	Yes (39%), No (61%)	Yes (54%) No (46%)

Table 2 shows survey questions which we asked from retailers based in Lahore and Islamabad areas. We visited Anarkali and Shah Alam market in Lahore which are two big wholesale markets. In Islamabad we visited weekly 'bazar' and I8 market. The results show that more strictness is present in Islamabad compared to Lahore area and customers are more environmental conscious in Islamabad compared to Lahore. We have added some pictures of retail markets in Appendix B.

3.4 Basic Assumptions and parameters

1. First, we will assume all three players are rational, because of incomplete information regarding analytical and decision-making skills of each player. In an evolutionary game model, at the beginning players are not affected by each other's strategies.

2. Strategies available to government are environmental regulations before introduction of Pakistan environment protection act of 2019 and environmental regulations after the introduction of this act. Regulations without the environment protection act means that government is not penalizing firms for ignoring the harmful effects of plastic production. Regulations with environment protection act means that government can impose restrictions on plastic manufacturing firms. In case of noncompliance the government can fine these firms. If government implements environmental regulation, then they will incur supervision and monitoring cost $\mathbf{SC_g}$ as well as cost of providing subsidies to firms who adopt business process innovation **PS**. When this act is imposed, firms will comply with it and incur investment cost of $\mathbf{IC_{m1}}$ because if they do not then they will have to face penalties imposed by government **PE**.

3. The strategies available for firms is complying with Pakistan environment protection act of 2019 and adopting business process innovation. They can receive the subsidy **PS** by the government in return for this. In contrast to this, if firms refuse to comply with the act, then they will face penalties **PE.** In this case the probability of fraudulent acts is **λ** and probability of government finding about these acts is **α.**

4. Strategy available for retailers is to accept the regulation, ***RA*** and sell eco-friendly bags to earn additional revenue from it, RS_{EB} or they can choose to ignore the environment act and keep using single-use plastic bags $\boldsymbol{RU_2}$.

5. The probability of firms adopting business process innovation is **b** and probability of firms using traditional processes for production is **1-b.**

6. The probability of government imposing environment protection act is **a** and probability of government regulation without environment protection act is **1-a.**

7. The probability of retailers accepting eco-friendly bags is **c** and probability of retailers using plastic bags is **1- c**.

   The description of each notation is present in table1. Based on all assumptions a payoff matrix is formulated and shown in table 3. Given all the assumptions and parameters of the proposed model a hybrid strategy is applied.

Table 3: Government-manufacturer-retailer evolutionary game model parameters

Parameters	Description
GR_{g1}	Government's revenue from the plastic bags manufacturers **process innovation** and **production of biodegradable bags** after the implementation of Pakistan Environmental Protection Act 2019 ($GR_{g1} > GR_{g2}$
GR_{g2}	Government's revenue from the plastic bags manufacturers **production of single-use plastic bags** using traditional business processes
GR_{g3}	Government's revenue from **retailer acceptance of using environment friendly bags** after the implementation of Pakistan Environmental Protection Act 2019
GR_{g4}	Government's **reputation revenue** after the implementation of Pakistan Environmental Protection Act 2019
SC_g	**Supervision cost** incurred by the government after the implementation of Pakistan Environmental Protection Act 2019
PS	**Tax incentives** or **production subsidies** received by the manufacturers for process innovation after the implementation of Pakistan Environmental Protection Act 2019 by the regulatory authorities
PE	**Penalty/fine imposed by the government regulatory authority** on plastic bags manufacturers those have not conform to the regulation or either manufactured sub-standard products
RM_{m1}	Revenue generated by manufacturers from **selling environmentally friendly bags**
RM_{m2}	Revenue generated by manufacturers from **selling traditional single use bags**
RM_{m3}	**Manufacturer revenue** from retailers who accepted the **usage of biodegradable bags**
IC_{m1}	The **investment cost** incurred by manufacturers for **business process innovation** and production of environment friendly bags ($IC_{m1} > IC_{m2}$)

Parameters	Description
IC_{m2}	The **investment cost** incurred by manufacturers for production of regular single use plastic bags
RU_1	**Retailer's utility** of using new **environment friendly bags**
RU_2	**Retailer r's utility** of using **single use plastic bags**
RS_{EB}	**Retailer's savings/revenue** after using new **environment friendly bags** instead of single use plastic bags
RA	**Retailer's acceptance** to use new **environment friendly bags** instead of single use plastic bags
P_1	**Degree of positive influence on retailer of new business process innovation** instead of traditional production methods to manufacture single use plastic bags
P_2	**Degree of positive influence on retailers for usage of environmentally friendly bags** instead of single use plastic bags
λ	Probability of **fraudulent acts**
α	Probability of **government finding out fraudulent manufacturers** not complying with environmental regulations
β	Probability of **retailers not accepting environment friendly practices**
μ	Threshold of P_1
ra_1, ra_2	Threshold of RA ($ra_1 < ra_2$)
a	Probability of **environmental regulations** imposed by the government
b	Probability of **manufacturers having process innovation and production of environment friendly bags**
c	Probability of **retailer acceptance to use environment friendly bags**

3.5 Hypothesis development

Based on the above assumptions and parameters for government, manufacturers, and retailers we have proposed the following hypothesis:

H1: According to the assumptions of evolutionary game theory, both government and manufacturers are bounded rational subjects. Strategy available to government is to either impose the Pakistan environment protection act of 2019 or to ignore this act and impose no environmental regulation. The probability of government choosing to impose this regulation is **a** and the probability of ignoring this regulation is **1-a** (where **a** lies between 0 and 1). The strategy available with manufacturer is either to adopt business process innovation and manufacture environment friendly bags or to continue practicing traditional processes and manufacture single-use plastic bags. The probability of adopting business

process innovation is **b** while the probability of practicing traditional processes is **1-b.**

H2: If government chooses to impose environmental regulations then cost of supervision and monitoring will be $\mathbf{SC_g}$ and government will earn reputation revenue of $\mathbf{GR_{g4}}$ from it. If manufacturer decides to adopt business process innovation, then incurred cost will be $\mathbf{IC_{m1}}$, subsidy given by the government for innovation will be **PS** and revenue from practicing innovation and selling environment friendly bags will be $\mathbf{RM_{m1}}$. Through process innovation of manufacturer, government can earn revenue of **GRg1** in the form of reduction in environmental degradation. If manufacturer decided to continue using traditional business processes then incurred cost will be $\mathbf{IC_{m2}}$, revenue to manufacturer from producing single-use plastic bags will be $\mathbf{RM_{m2}}$ while the revenue for government will be $\mathbf{GR_{g2}}$. Assuming that, business process innovation is better for the environment, manufacturers change their production processes and incur different costs, we can say that $\mathbf{IC_{m1} > IC_{m2}, GR_{g1} > GR_{g2}}$.

H3: If the manufacturer decides to ignore environment protection act of 2019, then manufacturer will be violating the regulation and committing fraud. The probability of committing fraud will be **λ,** and the probability of government identifying those manufacturers who violate the law is **α.** In this situation government will charge a penalty of **PE.**

H4: Retailers have two strategies, either they can use environment friendly bags, or they can opt for single-use plastic bags. The probability of retailers using environment friendly bags is **c** while probability of not using environment friendly bags will be **1-c** (where **c** lies between 0 and 1). The retailer's utility of using environmentally friendly bags is $\mathbf{RU_1}$ and their utility of using single-use plastic bags is $\mathbf{RU_2}$**.** Furthermore, retailers' acceptance to use new type of shopping bags is measured as **RA.**

H5: If retailers start using environment friendly bags, then they can earn $\mathbf{RS_{EB}}$ from selling them to customers. While the probability of not accepting environment friendly practices is **β.**

H6: When retailers start using environment friendly bags then awareness regarding benefits of environment increases among consumers, this increases government revenue by $\mathbf{GR_{g3}}$**.** Moreover, manufacturers revenue from retailers using environment friendly bags is $\mathbf{RM_{m3}}$. In addition to this, **P1** represents degree of positive influence on retailers

from using environment friendly bags and **P2** is degree of positive influence on retailers from usage of environment friendly bags.

3.6 Government-Manufacturer-Retailer game matrix

Table 4

Government	Manufacturers	Retailers	
		Environment friendly bags (c)	**Single use plastic bags (1-c)**
Environmental regulations (a)	**Business process innovation (b)**	$GR_1 + \beta GR_3 + GR_4$-PS-SC_G	$GR_1 + \beta GR_3 + GR_4$-PS-SC_G
		$RM_{m1} + \beta (2P_1\text{-}1) RM_{m3}$ +PS-IC_{m1}	CA [$(RM_{m1} + \beta (2P_1\text{-}1) RM_{m3}$ +PS-IC_{m1}]
	Traditional business processes (1-b)	$RU_1 + \beta RS_{EB}$ $GR_2 + \beta GR_3 + GR_4$-SC_G + λ [(α PE – (1-α) PS]	CA [$RU_1 + \beta RS_{EB}$] $GR_2 + \beta GR_3 + GR_4$-SC_G + λ [(α PE – (1-α) PS]
		(1-CA) [$(RM_{m2} + \beta (2P_2\text{-}1) RM_{m3}$ -IC_{m2}]- λ [(α PE – (1-α) PS]	[$(RM_{m2} + \beta (2P_2\text{-}1) RM_{m3}$ -IC_{m2}]- λ [(α PE – (1-α) PS]
No environmental regulations (1-a)	**Business process innovation (b)**	(1-CA) [$RU_2 + \beta RS_{EB}$] $GR_1 + \beta GR_3$-PS	[$RU_2 + \beta RS_{EB}$] $GR_1 + \beta GR_3$-PS
		$RM_{m1} + \beta (2P_1\text{-}1) RM_{m3}$ +PS-IC_{m1}	CA [$(RM_{m1} + \beta (2P_1\text{-}1) RM_{m3}$ +PS-IC_{m1}]
		$RU_1 + \beta RS_{EB}$	CA [$RU_1 + \beta RS_{EB}$]
	Traditional business processes (1-b)	$GR_2 + \beta GR_3$ −λPS	$GR_2 + \beta GR_3$ −λPS
		(1-CA) [$(RM_{m2} + \beta (2P_2\text{-}1) RM_{m3}$ -IC_{m2} + λ PS]	$RM_{m2} + \beta (2P_2\text{-}1) RM_{m3}$ -IC_{m2} + λ PS
		(1-CA) [$RU_2 + \beta RS_{EB}$]	$RU_2 + \beta RS_{EB}$

A replicator dynamic equation can be constructed using the above matrix by calculating average expected revenue of each player.

The government expected revenue while opting for environmental regulation is E_{G1}, the expected revenue while government opting for no environmental regulation is E_{G2} and the average expected revenue is $\overline{E_G}$.

The government expected revenue while opting for environmental regulation is as follows:

E_{G1} = bc($GR_1 + \beta GR_3 + GR_4$-PS-SC_G) + b(1-c)($GR_1 + \beta GR_3 + GR_4$-PS-SC_G) + c(1-b)[$GR_2 + \beta GR_3 + GR_4$-SC_G + λ [(α PE − (1-α) PS]] + (1-b)(1-c)[$GR_2 + \beta GR_3 + GR_4$-SC_G + λ [(α PE − (1-α) PS] (1)

The expected revenue while government opting for no environmental regulation is as follows:

E_{G2} = bc(GR_1 + βGR_3-PS) + c(1-b)(GR_2 + βGR_3 −λPS) + b(1-c) (GR_1 + βGR_3-PS) + (1-c)(1-b)

(GR_2 + βGR_3 −λPS) (2)

The average expected revenue is as follows:

$\overline{E_G}$ = aE_{G1} + (1-a) E_{G2} (3)

The differential dynamic equation of the government is as follows:

F(a) = $\frac{\partial a}{\partial t}$ = a($E_{G1} - \overline{E_G}$ (4)

F(a) = $\frac{\partial a}{\partial t}$ = a(1-a) ($E_{G1} - E_{G2}$ (5)

F(a) = $\frac{\partial a}{\partial t}$ = a(1-a) [- λ α (PE + PS) b + $GR_4 - SC_G$ + λα (PE + PS)] (6)

A manufacturer's expected revenue of choosing business process innovation is E_{M1}, the manufacturer expected revenue of choosing traditional business processes is E_{M2}, and the manufacturer average expected revenue is $\overline{E_M}$.

Now, manufacturer expected revenue of choosing business process innovation is as follows:

E_{M1} = ac[RM_{m1} + β (2P_1-1) RM_{m3} +PS-IC_{m1}] + (1-a)(1-c)RA[RM_{m1} + β (2P_1-1) RM_{m3} +PS-IC_{m1}] +a(1-c) RA[RM_{m1} + β (2P_1-1) RM_{m3} +PS-IC_{m1}] + c(1-a)[[RM_{m1} + β (2P_1-1) RM_{m3} +PS-IC_{m1}] (7)

The manufacturer expected revenue of choosing traditional business processes is as follows:

E_{M2} = ac(1- RA)[(RM_{m2} + β (2P_2-1) RM_{m3} -IC_{m2} - λ [(α PE – (1-α) PS]] + a(1-c)[(RM_{m2} + β (2P_2-1) RM_{m3} -IC_{m2} - λ [(α PE – (1-α) PS]] + c(1-a) (1-CA) [(RM_{m2} + β (2P_2-1) RM_{m3} -IC_{m2} + λ PS] + (1 -a) (1- c) [(RM_{m2} + β (2P_2-1) RM_{m3} -IC_{m2} + λ PS] (8)

The manufacturer average expected revenue is as follows:

$\overline{E_M}$ = bE_{M1} + (1-b) E_{M2} (9)

Now assuming that W_1 = RM_{m1} + β (2P_1-1) RM_{m3} +PS-IC_{m1} and W_2 = RM_{m2} + β (2P_2-1)RM_{m3} -IC_{m2} + λ PS. The differential dynamic equation of manufacturer is as follows:

F(b) = $\frac{\partial b}{\partial t}$ = b($E_{M1} - \overline{E_M}$ (10)

F(b) = $\frac{\partial b}{\partial t}$ = b(1-b) ($E_{M1} - E_{M2}$ (11)

F(b) = $\frac{\partial b}{\partial t}$ = b(1-b)[W_1(c + RA – cRA) – – λαa (PE + PS))(1-cRA)] (12)

The retailer's expected revenue of choosing environment friendly bags is E_{R1}, the retailer expected revenue of choosing single use plastic bags is E_{R2}, and the retailer average expected revenue is $\overline{E_R}$.

The expected revenue of retailer using environment friendly bags is as follows:

E_{R1} = ab(RU_1 + βRS_{EB}) + a(1-b)(1-RA)(RU_2 + βRS_{EB}) + (1-a)b(RU_1 + βRS_{EB}) + (1-a)(1-b)(1-RA) (RU_2 + βRS_{EB}) (13)

The expected revenue of retailer using single use plastic bags is as follows:

E_{R2} = abRA(RU_1 + βRS_{EB}) + a(1-b) (RU_2 + βRS_{EB}) + RAb(1-a) (RU_1 + βRS_{EB}) + (1-a)(1-b) (RU_2 + βRS_{EB}) (14)

The average expected revenue of retailer is as follows:

$$\overline{E_R} = cE_{R1} + (1\text{-}c)E_{R2} \tag{15}$$

The differential dynamic equation of retailers is as follows:

$$F(c) = \frac{\partial c}{\partial t} = c(E_{R1} - \overline{E_R} \tag{16}$$

$$F(c) = \frac{\partial c}{\partial t} = c(1\text{-}c) (E_{R1} - E_{R2} \tag{17}$$

$$F(c) = \frac{\partial c}{\partial t} = c(1\text{-}c)[[RU_1 + \beta RS_{EB}\text{-} (RU_1 - RU_2)RA]b - (RU_2 + \beta RS_{EB})RA] \tag{18}$$

Analysis of evolutionary stability strategies

Based on equations (6), (12) and (18), the dynamic system equation for the presented game model is as below:

Now, let's assume that $F(a) = F(b) = F(c) = 0$, it can be further examined that there are total eight equilibrium points in the three dimensional dynamic system which includes (0,0,0), (1,0,0), (0,1,0), (0,0,1), (1,1,0), (1,0,1), (0,1,1) and (1,1,1). It is important to note that it is not necessary that all provided eight strategy combinations are stability strategies. Equilibrium point (1,0,0) shows that government opts for environmental regulations, but manufacturers continue using traditional processes and retailers keep on using single-use plastic bags. If government does not impose environmental regulation, then firms will not adopt sustainable business processes in order to earn greater revenue. This implies that points (0,1,0) and (0,1,1) will be omitted. Regarding the Jacobian matrix, Lyapunov stability criteria is used which states that equilibrium is stable when eigen values of Jacobian matrix are negative (Moylan & Hill, 1978). These values are shown in Table 5.

$$J_1 = \begin{bmatrix} \frac{\partial F(a)}{\partial a} & \frac{\partial F(a)}{\partial b} & \frac{\partial F(a)}{\partial c} \\ \frac{\partial F(b)}{\partial a} & \frac{\partial F(b)}{\partial b} & \frac{\partial F(b)}{\partial c} \\ \frac{\partial F(c)}{\partial a} & \frac{\partial F(c)}{\partial b} & \frac{\partial F(c)}{\partial c} \end{bmatrix} \tag{20}$$

Table 5: Equilibrium points and eigenvalues of the Jacobian matrix in correspondence to each equilibrium point

Equilibrium Point	Eigenvalues		
(0,0,0)	$GR_4 + \lambda\alpha(PE + PS) - SC_G$	$RAW_1 - W_2$	$-RA(RU_2 + \beta RS_{EB}$
(1,0,0)	$SC_G - GR_4 - \lambda\alpha(PE + PS)$	$RAW_1 - W_2 + \lambda\alpha(PE + PS)$	$-RA(RU_2 + \beta RS_{EB}$
(0,0,1)	$GR_4 + \lambda\alpha(PE + PS) - SC_G$	W_1 - (1-RA) W_2	$RA(RU_2 + \beta RS_{EB}$
(1,1,0)	$SC_G - GR_4$	W_2 - RAW_1 - $\lambda\alpha(PE + PS)$	(1-RA)$(RU_1 + \beta RS_{EB}$
(1,0,1)	$SC_G - GR_4 - \lambda\alpha(PE + PS)$	$W_1 - W_2 + \lambda\alpha$(1-RA) $(PE + PS)$	$RA(RU_2 + \beta RS_{EB}$
(1,1,1)	$SC_G - GR_4$	$W_2 - W_1 - \lambda\alpha$(1-RA) $(PE + PS)$	(1-RA)$(RU_1 + \beta RS_{EB}$

Eigenvalues show the stability of each equilibrium point. There are 3 equilibrium points in the three-dimensional dynamic system. These 3 stable strategies have been analyzed below:

Scenario1: When $GR_4 + \lambda\alpha(PE + PS) < SC_G$ and $RAW_1 < W_2$ then cost of implementing environmental regulations is higher than reputation revenue of government and manufacturers earn more revenue from using traditional business processes compared to business process innovation. Therefore, stable strategy will be, (no environmental regulation, using traditional processes, using single-use plastic bags).

Scenario 2: When $GR_4 - \lambda\alpha(PE + PS) > SC_G$ and $RAW_1 + \lambda\alpha(PE + PS) < W_2$ then cost of implementing environmental regulation is less than reputation revenue of government and manufacturers earn more revenue from using traditional business processes compared to business process innovation. Therefore, stable strategy will be, (environmental regulation, using traditional processes, using single-use plastic bags).

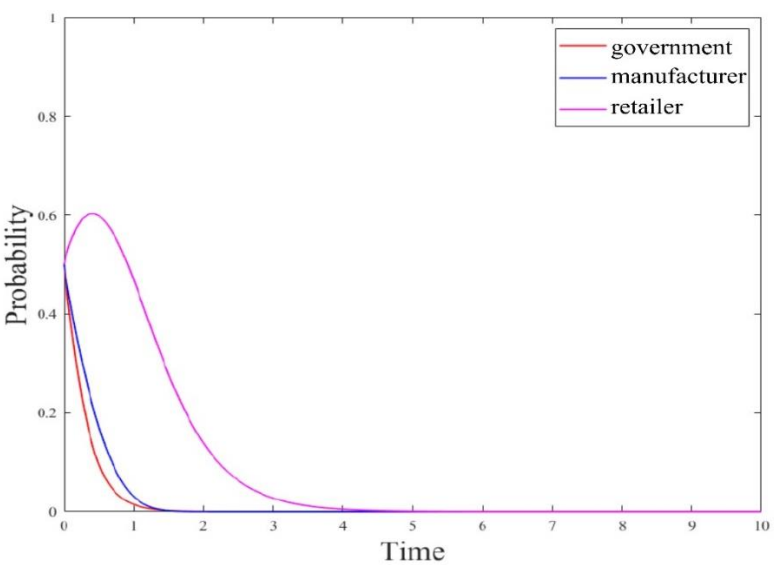
Scenario3: When $GR_4 > SC_G$ and $W_2 - \lambda\alpha$(1-RA) $(PE + PS) < W_1$ then cost of implementing environmental regulation is less than reputation revenue of government and manufacturers earn more revenue from adopting business process innovation compared to traditional processes. Therefore, stable strategy will be (environmental regulation, adopt business process innovation, use environment friendly bags).

3.7 Simulation Analysis

In this section we have used MATLAB and Wolfram Mathematica version 11.3 to conduct simulation analysis of the above-mentioned game theory model in order to assess each player's strategy under different conditions. For this purpose, we have looked at the evolution strategy of each player and then we have looked at the effect of initial strategy of players; environmental regulations, manufacturer willingness and retailer acceptance on the results of the dynamic evolutionary game. We have outlined three scenarios to analyze to government-manufacturer-retailer stability strategy.

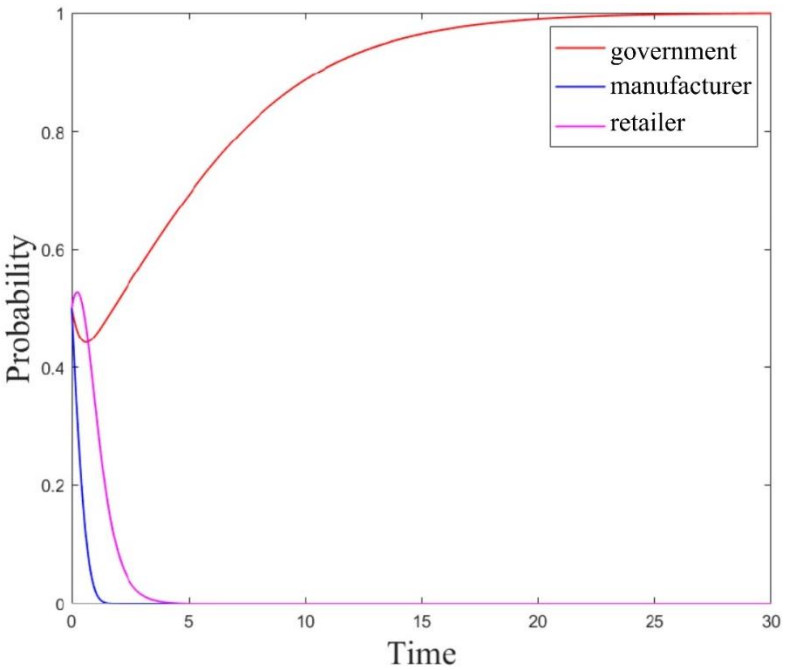
Scenario1: When the cost of imposing and implementing the Pakistan environment protection act of 2019 is high for government and manufacturers feel that adopting business process innovation is costly then the parameters of the evolutionary game model will be: $GR_{g4}=4$, $SC_g=10$, $PE=8$, $PS=1$, $RM_{m1}=9$, $RM_{m2}=15$, $RM_{m3}=8$, $RS_{EB}=5$, $IC_{m1}=3$, $IC_{m2}=1$, $RU_1=5$, $RU_2=1$, $P_1=0.5$, $P_2=0.28$, $RA=0.5$, $\lambda=0.5$, $\alpha=0.5$, $\beta=0.5$. In this case the system stability strategy is (no government environment regulation, manufacturers using traditional business processes and retailers using single-use plastic bags). The evolutionary path for this strategy is shown in figure 4.

Figure 4. Evolutionary results under Scenario 1.



Scenario 2: When the revenue for the government of imposing Pakistan environment protection act of 2019 is high and the cost of business process innovation for manufacturers is high then the parameters of the evolutionary game model will be: $GR_{g4}=8$, $SC_g=10$, $PE=8$, $PS=1$, $RM_{m1}=9$, $RM_{m2}=15$, $RM_{m3}=8$, $RS_{EB}=5$, $IC_{m1}=3$, $IC_{m2}=1$, $RU_1=5$, $RU_2=1$, $P_1=0.5$, $P_2=0.28$, $RA=0.5$, $\lambda=0.5$, $\alpha=0.5$, $\beta=0.5$. In this case the system stability strategy is (government imposing environment regulation, manufacturers using traditional business processes and retailers using single-use plastic bags). The evolutionary path for this strategy is shown in figure 5.

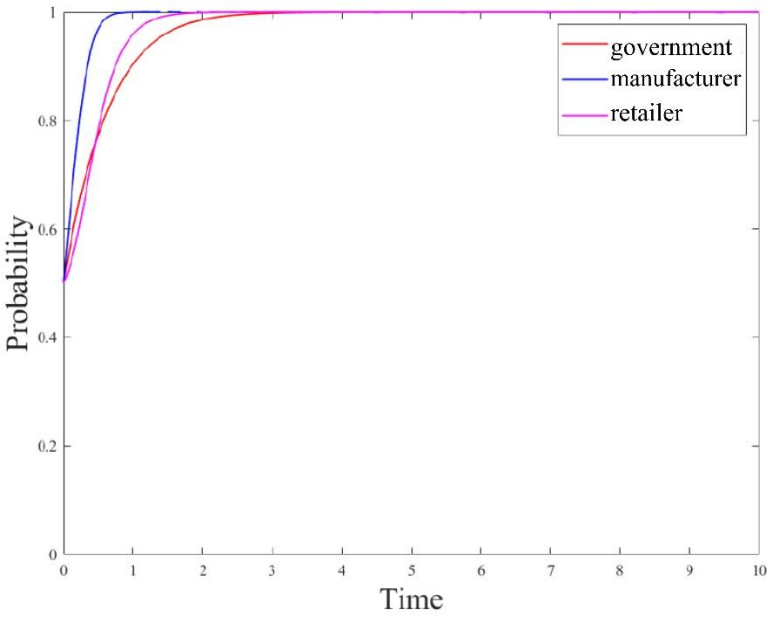
Figure 5: Evolutionary results under Scenario 2



Scenario 3: When the revenue for the government of imposing Pakistan environment protection act of 2019 is high and cost of business process innovation for manufacturers is low then the parameters of the evolutionary game model will be: $GR_{g4}=12$, $SC_g=10$, $PE=8$, $PS=1$, $RM_{m1}=15$, $RM_{m2}=9$, $RM_{m3}=8$, $RS_{EB}=5$, $IC_{m1}=3$, $IC_{m2}=1$, $RU_1=5$, $RU_2=1$, $P_1=0.5$, $P_2=0.28$, $RA=0.5$, $\lambda=0.5$, $\alpha=0.5$, $\beta=0.5$. In this case the system stability strategy is (no government environment regulation, manufacturers using traditional business processes and retailers using

single-use plastic bags). The evolutionary path for this strategy is shown in figure 6.

Figure 6: Evolutionary results under Scenario 3



Scenario 3 offers the ideal system stability strategy however scenario 1 and 2 try to identify how that ideal strategy is achieved. Hence, this section has discussed the effect of the important parameters on the system strategy and how each strategy achieves its ideal state. We have looked at the impact of retailer acceptance on evolutionary results under scenario 1, the impact of environmental regulation on evolutionary results under scenario 2 and lastly we have looked at the impact of initial strategy of each player on evolutionary results under scenario 3.

a. Exploration of player's strategy evolution under different scenarios

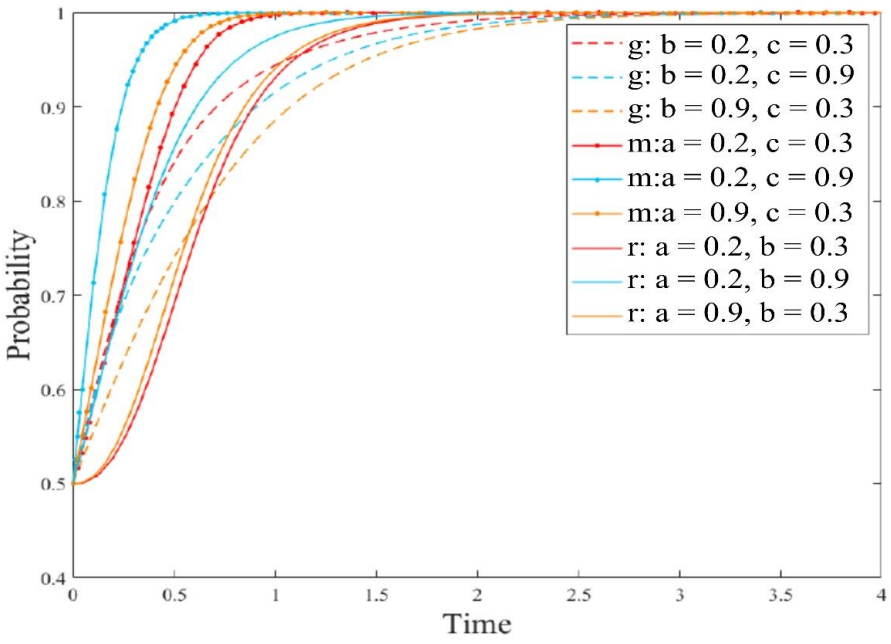
The evolutionary results of each scenario are depicted in figures 4-6. The combinations under each scenario are (0,0,0) for scenario 1, (1,0,0) for scenario 2 and (1,1,1) for scenario 3. At this point the evolutionary trend of the retailer strategy is similar to the manufacturer strategy, although the retailer strategy reaches its stable path slower than the manufacturer strategy. Government and manufacturer stability strategy relies on costs and revenues while retailer strategy is

dependent on whether manufacture practices business process innovation or not. According to the defined parameters under all scenarios, the retailer earns more revenue from using environment friendly bags as opposed to single-use plastic bags but the simulation results show a different picture. Scenario 1 and 2 show that the stability strategy for the retailer would be to use single-use plastic bags and just under scenario 3 the stability strategy is to shift to environment friendly bags. This might be because, single-use plastic bags are more in demand with the consumers.

b. Impact of initial strategy on the evolutionary results.

The evolutionary results of the three-player game are shown in figure 7. This figure depicts the results after the probability values (a, b, c) were changed for scenario 3. It shows that how changes in probability can affect the rate at which each player reaches its steady state. The higher is the probability (b) of manufacturers adopting business process innovation the more time it takes for government environmental regulation to reach its steady state. This might happen because if manufacturers have a high probability of practicing business process innovation, then probability of fraudulent acts (λ) will be lower and government regulation will not be needed. Moreover, compared to environmental regulations, retailers have a higher effect on manufacturers willingness to adopt business process innovation. This means that the higher the probability of retailer's acceptance towards environment friendly bags is, the faster the manufacturer will adopt business process innovation to reach the steady state. This happens because manufacturer want to satisfy the demand of the retailers who are their direct customers. The strategy of the retailer is affected by manufacturer's strategy. The higher is the probability of manufacturers adopting business process innovation the quicker retailers opt for environment friendly bags to reach their steady state.

Figure 7: Evolutionary results of strategy with different player's initial strategy (g: government, m: manufacturer, r: retailer)



c. Influence of government environmental regulations on evolution

Simulation results of scenario 2 are depicted in figure 8 and 9. At this point the strategy is (environmental regulation, manufacturers using traditional business processes, retailers using single-use plastic bags). Figure 8 shows that when government offers tax incentives and subsidies to manufacture environment friendly bags after implementation of Pakistan environment protection act of 2019 then manufacturers will shift from traditional business processes to sustainable business processes. Similarly, retailers will move away from using single-use plastic bags and towards environment friendly bags. In contrast, government strategy has shifted to no regulation. This might be because manufacturers have altered their production processes. Furthermore, due to high cost of monitoring and supervising government can move away from imposition of environmental regulations. Moreover, figure 9 shows that if government increases the number of penalties charged for violation of Pakistan environment protection act of 2019, then it will incentivize manufacturers to adopt business process innovation. Due

to high penalties, firms might reduce engaging in fraudulent activities, but it can increase cost of monitoring for the government due to which environmental regulation will fall and steady state strategy for government will be no environmental regulation.

Figure 8: Evolutionary results of strategy with different tax incentives and subsidies (PS)

(g: government, m: manufacturer, r: retailer) (PS: Tax incentives or production subsidies received by the manufacturers for process innovation after the implementation of Pakistan Environmental Protection Act of 2019)

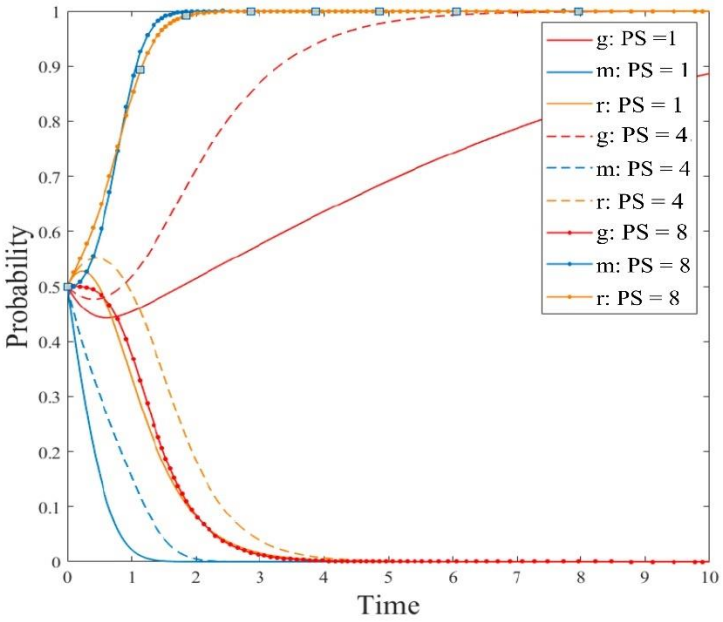
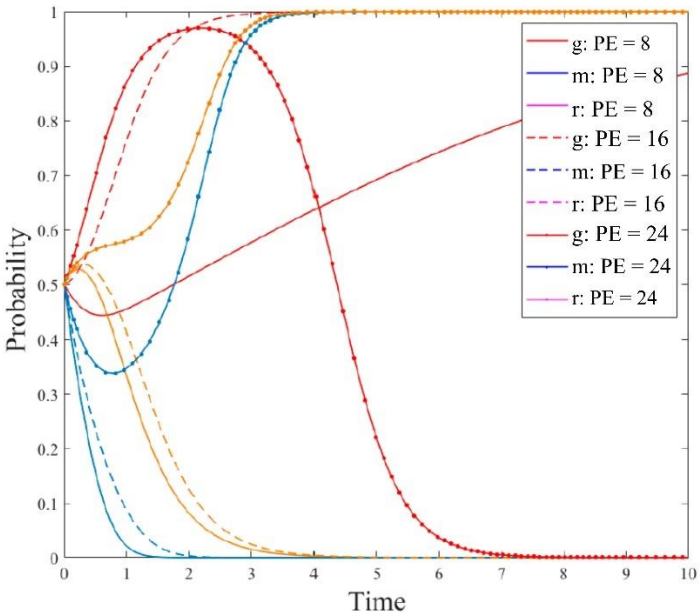


Figure 9: Evolutionary results of strategy with different penalties/fines (PE) (g: government, m: manufacturer, r: retailer) (PE: Penalty/fine imposed by the government regulatory authority on plastic bags manufacturers those have not conform to the regulation or either manufactured sub-standard products)



d. Influence of retailer utility on evolution

This section discusses the effect of retailer utility. As the utility obtained from using environment friendly bags is proportionate to positive influence on retailer, therefore according to the parameter conditions of scenario 1, we made changes in the retailer's utility (RU_1) and assessed the effect of degree of positive influence P_1 on manufacturers simultaneously under different scenarios.

Figure 10: Evolutionary results of strategy of the government

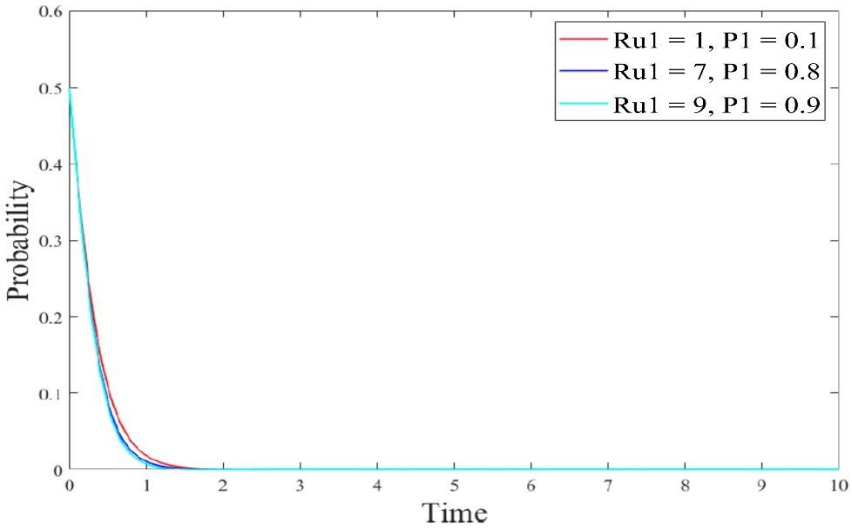


Figure 11: Evolutionary results of strategies of manufacturer and retailer (m: manufacturer, r: retailer) (Ru1: retailer's utility from using environment friendly bags, P1: degree of positive influence on retailer of business process innovation)

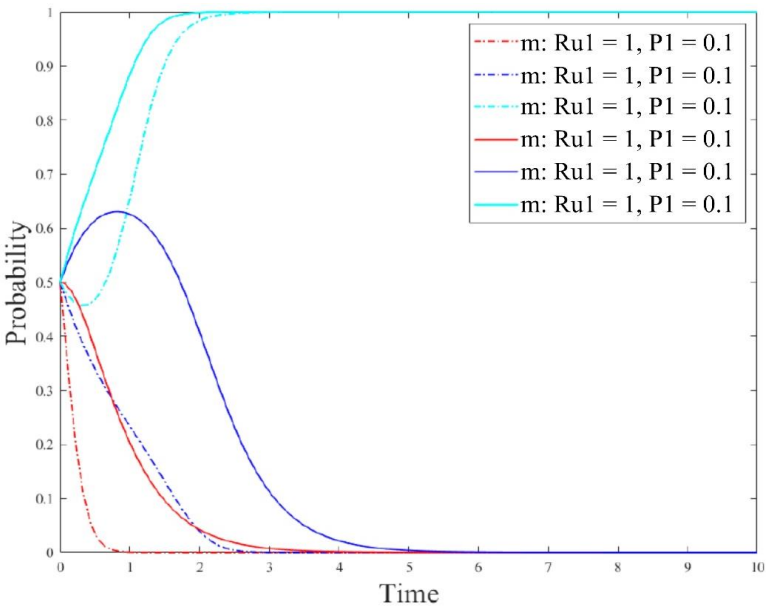


Figure 10 depicts the effect of retailer utility from using environment friendly bags on government's strategy. Retailer utility has a small impact on government strategy because government decisions are not influenced by external factors but they are based on its own cost-benefit analysis. Figure 11 shows that the threshold value $\boldsymbol{\mu}$ of P1 lies between 0.8 and 0.9, this indicates that when $P1 < \boldsymbol{\mu}$ then more time is taken for manufacturer and retailer strategy of using traditional business processes and single-use plastic bags to reach its steady state. However, when $P1 > \boldsymbol{\mu}$ then manufacturers and retailers will change their strategy to business process innovation and using environment friendly bags respectively. Moreover, manufacturer strategy approaches steady state slower than retailer strategy. It might be because manufacturers change their strategy in response to changes in retailer strategy.

e. Influence of retailer acceptance on evolution

Figure 11 shows that when $RU1 > \mu$ which is its threshold value then, the retailer strategy approaches its steady state faster than the manufacturer strategy. The simulation results are different from those in figure 6. To identify the reason for this difference we have set our parameter setting so that retailer acceptance, RA is used to analyze system evolution results. These results are shown in figures 12 and 13.

Figure 12: Evolutionary results of government strategy
(RA: Retailer acceptance of environment friendly bags)

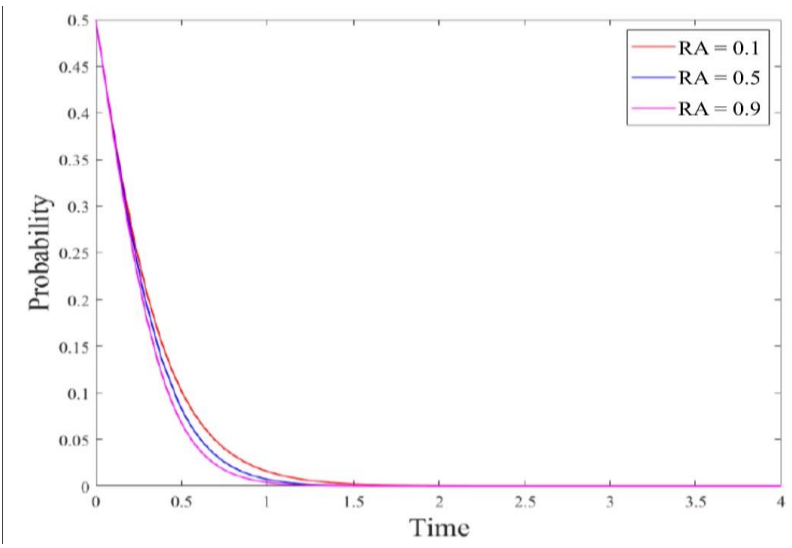
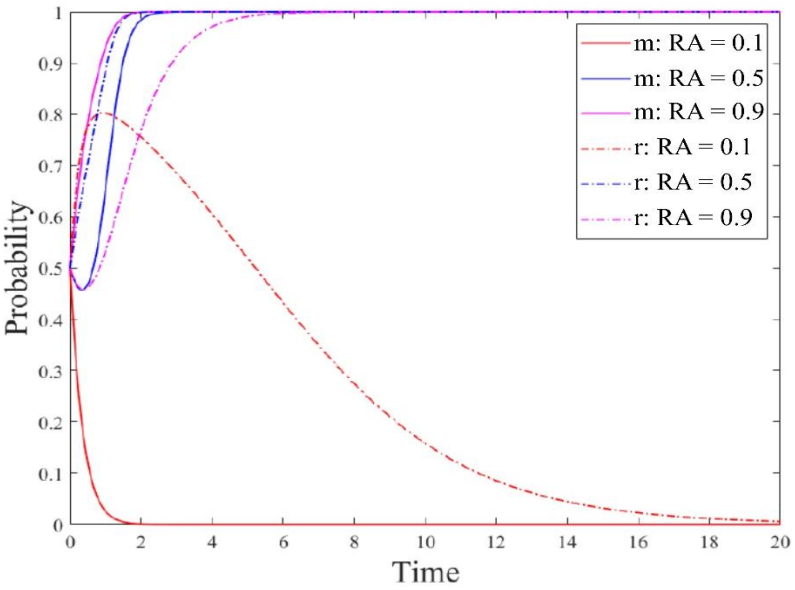


Figure 13: Evolutionary results of manufacturer and retailer strategies
(m: manufacturer, r: retailer)



These figures show the evolutionary results of government, manufacturers, and retailer strategies under various retailer acceptance. Figure 12 shows that a high value of RA means that government approaches its steady state quickly, but RA does not change government strategy from no environmental regulation to environmental regulation. This might be because government strategy is not directly influenced by retailer acceptance, and it mostly revolves around costs and revenue associated with imposing environment regulations. Furthermore, figure 13 shows that the threshold value of ra_1 is between 0.1 and 0.5. If RA is less than ra_1, the stable strategy for manufacturers is to use traditional business processes and the ideal strategy for retailers is to keep using single-use plastic bags. However, when RA exceeds ra_1then stable strategy for manufacturers is to adopt sustainable business processes and for retailers to switch to environment friendly bags. Additionally, when retailer acceptance lies between 0.5 and 0.9 then the threshold value becomes ra_2**.** When retailer acceptance lies between 0.5 and ra_2 then retailer achieves steady state faster than manufacturer. This happens because if initial strategy of the manufacturer was to use traditional business processes then the strategy might change in response to attitudes of retailers towards environment friendly bags.

4. Discussion of results

We have looked at the simulation results as well as empirical verification, in this section we have analyzed the results, discussed wider applications of our results and limitations of the paper.

4.1 Discussion of simulation results

The retailer strategy is affected by manufacturer strategy because single-use plastic bags are considered a necessity. This indicates that manufacturers are important players in the distribution and production of single-use plastic bags, due to which government should impose regulation.

Simulation results show that once manufacturers choose business process innovation strategy then government choose no environmental regulation strategy because of high monitory costs. But, government should continue to regulate manufacturers to discourage them from using traditional processes again.

When P1$>\ \mu$ ($0.8<\ \mu<0.9$) and when RA$<ra_1$($0.1<ra_1<0.5$) or RA$>ra_2$($0.5<ra_2\ <0.9$, the manufacturer strategy will achieve its steady state faster than retailer strategy. Therefore, manufacturers should take the first step to protect the environment by using sustainable business processes. Government should also create awareness among the public of the ecologically damaging effects of single-use plastic bags.

4.2 Wider applications

Environmental regulations imposed by government have a long term impact on multiple fronts. At macro level it leads to achievement of sustainable goals as is reflected from the manufacturer element where manufacturer will adopt sustainable business processes whereas at the retailer front they will go for environment friendly bags. This will facilitate in national transition aiming towards circular economy. Adopting this strategy has global implications because internationally, most developed economies have moved away from using traditional methods that produce carbon emissions by adhering to environment friendly practices. In the case of Pakistan, its economy is based on exports and carbon emission rates are huge due to which environmental damage is a lot. In order to promote a circular economy, government should take

manufacturers and retailers into confidence so that everyone is on board with the new laws. After the environment protection act of 2019 was introduced, many plastic bag manufacturers imported non-woven bag making machines to manufacture non-woven bags as an alternative to single-use plastic bags. During COVID-19 these non-woven machines were used to manufacture surgical face masks. After COVID-19 and during it, restrictions on manufacturing and usage of single-use plastic bags decreased. Furthermore, the raw material which is used to manufacture non-woven bags is short in the market due to which cost of manufacturing is high. Therefore, many manufacturers have returned to manufacturing single-use plastic bags. On the retailer front, those retailers who have multiple branches and are in the public's eye are using non-woven bags as opposed to single-use plastic bags to avoid criticism from the public. In contrast small retailers who are residing in wholesale markets of Rawalpindi and Lahore have continued using single-use plastic bags. The results of this paper indicate the importance of curbing plastic pollution. Government and regulatory bodies should provide import subsidies to manufacturers to encourage them to manufacture environment friendly bags. Government should reward those manufacturers who come up with plans to reduce and recycle plastic bag waste. It should create awareness among retailers by giving tax benefits to those retailers who use environment friendly bags. The government should educate general public about the damages caused by single use plastic bags. This will alter consumer preference from single-use plastic bags to environment friendly bags.

4.3 Limitations of research

This paper has a few limitations which future researchers can address. Firstly, in this paper we have focused on the Lahore region of Pakistan and looked at few wholesale markets. Our sample size was relatively small for empirical analysis. When looking at the effects of retailer strategy we did not consider the corporate social responsibility objectives of retailers which can alter their behavior towards single-use plastic bags. Future research can incorporate more regions of Pakistan and can also draw comparison of manufacturer strategy before and after the implementation of Pakistan environment protection act of 2019.

5. Conclusion

In this paper we have constructed a three-player dynamic replicator evolutionary game model in which government, plastic bag manufacturers and retailers are the main players. This model was constructed to evaluate the effects of Pakistan environment protection act of 2019. In this model we looked at the changes in manufacturer strategy in response to changes in strategy of government and retailers. Lastly, through simulation this paper looked at the evolution of different player's strategies under different scenarios and its influence each player's initial strategy. The few conclusions that were drawn from this exercise were firstly, government strategy is not influenced by outside factors but depends on own costs and revenues. In contrast, manufacture strategy is dependent on retailer strategy. If government offers subsidies to manufacturers, then they can invest in business process innovation which will be ecologically beneficial but if manufacturers are penalized for fraudulent practices, then environmental regulation might not be effective because of high monitoring and supervision costs. Lastly, retailer views about environment friendly bags plays an important role in influencing business decisions.

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Appendix A: Manufacturing Process

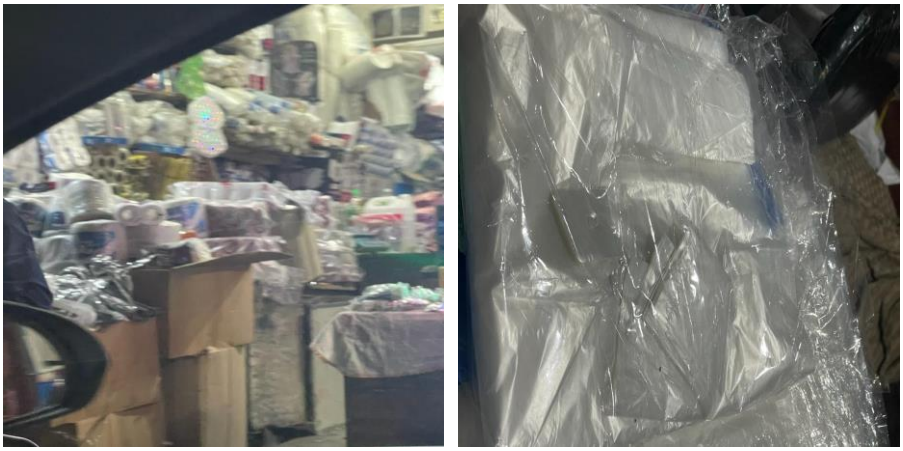
Plastic granules used to manufacture single use plastic bags

Biodegradable chemical which is used for business process innovation

Extrusion machine used to melt plastic granules and give them a sheet like look

Machine that cuts plastic sheet according to required size

Appendix B: Retail Markets



Wholesale market in Lahore using plastic bags

Retailer in Islamabad I8 market using environment friendly bags

A shop selling single-use plastic bags at Shah Alam market in Lahore

The Lahore School of Economics was established in 1993 as a private, non-profit university with the goal of developing world class teaching and research in Pakistan. The objectives of the LSE are to prepare young Pakistanis to undertake research in economics, finance, banking, business management, industry, and development, in order to deepen their understanding of, and be able to productively contribute to, the major issues and policies that impact Pakistan and Asia at large.

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Innovation and Technology Centre,
The Lahore School of Economics,
Intersection of Main Boulevard, Burki Road,
Phase VI, DHA, Lahore 53200, Pakistan
Tel: +92-(0)42-3656-0969
URL: https://itc.lahoreschool.edu.pk
Email: ayeshakh@lahoreschool.edu.pk