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Dynamic pricing and green investments under conscious, emotional, and rational consumers

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ABSTRACT

We consider behavioral issues in a new dynamic model in which a manufacturer (M) makes pricing and green investment decisions while facing heterogeneous customers including emotional, conscious, and rational consumers. Emotional consumers base their purchasing decisions on M's green investments. Their emotions are stochastic, dynamic, and accumulate over time. The investment is made over time and is subject to time-to-build so that there is a time-lag between investment and production. Differently, conscious consumers respond to both green investments and prices and have no memory on the M's past green initiatives. The rational consumers are not sensitive to environmental issues and base their decisions only on product price. Our findings suggest that M should realize that emotional consumers have the largest impact on investments, prices, and profits. Therefore, firms should first think to satisfy the emotional consumers and then all other segments. When firms have environmental targets or restrictions, all segments must be satisfied independent of their impact on the profits. This finding contributes to the literature by highlighting that the trade-off between economic and environmental performance also exists in presence of consumer segments.

1. Introduction

Green products have been partially accepted by the markets. The consumers do not fully trust the green goods performance, thus the environmental preservation and protection only becomes a second order target (Ramani and De Giovanni, 2017; Saunila et al., 2018). Guide and Li (2010) explain that the demand market can be divided into three consumers groups: a) consumers who purchased new products will continue to purchase new products after they return the end-of-use goods; b) consumers who purchase new products will evaluate the possibility to purchase used products in the future; c) consumers who are environmentally friendly and conscious do only purchase green products to satisfy their needs. Although this classification reflects the composition of an actual marketplace, the literature on vertical relations covering remanufacturing and reverse logistics fully disregards this demand segmentation (see a recent survey by De Giovanni and Zaccour (2019a).

The economic theory and the operations management literature have mainly focused on a single consumer type in that consumers are fully rational and purchase the goods based only on the purchasing prices. However, the literature on environmental psychology examines the impact of green consumers. In a recent article, Joshi and Rahman (2015) review papers that have examined factors effecting green purchase behavior. De Giovanni (2014) introduces a dynamic model in which firms accumulate consumers' green consciousness by investing in green activity programs. Hereby, the market is then composed of green consumers only. Although several firms can be involved in the product collection and invest in green activity programs, the firms' green efforts do not translate into larger demand. Rather, they play an operational role aiming at reducing the marginal production cost. Furthermore, the literature does not model at all the relationship between green efforts and consumers' contribution to the environment.

In this paper, we distinguish consumers considering their evaluation of traditional levers like prices as well as new levers like the firms' environmental commitments. For each consumer type, we model a demand function to capture their behavior; later, we unify all those in a model to be solved. We identify three consumer segments: 1. rational consumers, who purchase by only evaluating the product price; 2. emotional consumers, who only consider the contribution that firms

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exert to the environment before deciding whether to purchase; 3. conscious consumers, who consider both the purchasing price and the firm's contributions to the environment when making their decisions. To model emotional consumers, we distinguish their behaviors into two sub-segments: high and low emotional consumers. In particular, we assume that their aggregate demand is subject to a certain stochastic shock. By doing so, we isolate the effect of emotions on the purchasing decisions. Then, the manufacturer needs to set its strategies according to the shocks experienced and reduce the uncertainty by acquiring external information from a consulting company (Mattsson and Weibull, 2002). The cost for the consulting service also depends on the random shock. All segments are exposed to the same product; hence, the manufacturer has to fix the optimal strategies by considering the potential sales from all clusters. Independent of the market composition, the manufacturer offers a green product, which is defined as a product designed to minimize the environmental impacts during its whole life-cycle and even after it is of no use (Sdrolia and Zarotiadis, 2019). By keeping this general definition, our framework accomodates for both simple green activities to make the product greener (e.g., eco-innovation for decreasing the energy consumption) and atypical activities allowing for a second-life (e.g., remanufacturing and recycling).

To model conscious consumers, we distinguish consciousness from emotions and assume that the perception of conscious consumers toward the green product is instantaneous and memoryless (Damasio, 1999). At a given time conscious consumers base their purchasing decisions on price and their interpretation of *M*'s green investment initiatives/announcements. In fact, this demand segmentation or consumer type is parallel to psychology definition of behavioral responses. We differentiate consciousness from emotions because while the former is formed as a result of the consecutive sequence of attention, perception, and action, the latter is more general and provides a ground for extended consciousness by amalgamating old experiences with new ones (Damasio, 1999; Funk et al., 2009b). Consequently, while conscious consumers react to the green investments at a given time, emotional consumers expands the scope of consciousness by remembering the past green initiatives and then processing them along with the current ones, with the idea of evaluating all possible rebound effects as well (Murad et al., 2020). The demand heterogeneity has also been explored in the literature of behavioral operations. The rationale behind this stream is that the consumer heterogeneity leads consumers to behave differently while firms need to optimize to pursue market objectives (Conlisk, 1996). When firms and consumers are rational, the optimal solutions may be easily derived. In our framework, some consumers are rational since they only base their decisions on price. Differently, the other segments' decisions are also influenced by the firms' green activities.

We contribute to this domain by developing a dynamic model in which a manufacturer makes pricing and green investment decisions in different moments in time. As in De Giovanni and Zaccour (2019b), within the dynamic model that we develop, the manufacturer can adopt either a skimming or a penetration strategy. A skimming pricing strategy applies when the manufacturer sets high prices in the beginning of a planning horizon and decreases them over time. In contrast, a penetration pricing strategy allows the manufacturer to set low prices in the beginning of the planning horizon and increases increases them over time after acquiring a sufficient portfolio of consumers. The green investments exert a marketing role for both emotional and conscious consumers while also contributing to the used product return rate (Preeker and De Giovanni, 2018). As in Zhang and Yousaf (2020), they contribute to the development of the environmental consciousness, which explains the consumers' understanding of green issues, recognize the firm's efforts in developing green goods and preserve the environment for future generations. The manufacturer is also subject to a product return function, which mainly depends on the green activity efforts. That is, when consumers reach the end-of-use stage, they return their products which have some residual value that the firm can appropriate. We analyze the trade-offs emerging from a setting in which consumers return the used products late in the future, hence undertaking environmentally responsible behavior by fully exploiting the residual value of goods before returning them. We analyze the manufacturer's behavioral changes when it is exposed to all consumers categories and product returns at the same time. We then compare the results under the cases in which some market segments are ignored.

Our results suggest that the manufacturer should adjust its behavior to consider all shocks emerging in the market. This will allow the company to extract the largest economic value from the market. The presence of emotional consumers will pose challenges for the manufacturer as it has to make decisions under uncertainty. Furthermore, it will shift implementing from a penetration pricing strategy to a skimming pricing strategy depending on the emotions and green consciousness levels. In particular, we observe that this shift will apply to high emotional consumers, while the penetration strategy should in general be applied in the presence of low emotional consumers. Finally, the manufacturer should adopt a skimming strategy when the emotional sensitivity to green product is high and/or price sensitivity of conscious consumers is high.

While our current model involves one decision maker which relatively renders a tractable solution and provides economic intuition to assess the role of different psychological behaviors, it may be generalized to cover a competition framework. However, Geanakoplos et al. (1989) argue that standard games may not be suitable to incorporate emotions into strategic situations. They develop the theory of psychological games involving one player's beliefs about opponent's beliefs as well as strategic choices. Incorporating psychological behavior such as emotions into economic analysis is rare (Elster, 1998). Especially, competition framework with strategic considerations in the presence of emotions and consciousness has not been studied extensively (Dufwenberg, 2002). In a dynamic optimization setting, we model emotions and consciousness as continuous state variables which impact demand functions.

The remaining of the paper is organized as follows. Section 2 introduces the theoretical model and Section 3 analyzes optimal decisions when all consumers segments are considered. Section 4 presents a numerical analysis to gain insights about the likely impact of key model parameters. Sections 5, 6 and 7 examine special cases where a subset of consumer groups is considered and compared to when all consumer types are covered. Section 8 analyses the effect of product returns on pricing and green investment decisions and Section 9 briefly concludes with future research avenues.

2. Model

We formulate a dynamic model in which a manufacturer (*M*) produces a green product such as electric car, green panel and barrier, refurbished electronics, green clothes, etc. The dynamic formulation is needed to consider the effects of emotions on green products, which are soft element built over time (De Giovanni and Ramani, 2017). *M* sets the optimal pricing and green investment strategies under uncertainty in a dynamic market, which is composed of three distinctive demand segments: emotional consumers, conscious consumers and rational consumers. Each segment is influenced by the firm's strategies in various ways as we explain next.

There are three periods as depicted in Fig. 1. *M* invests in green efforts, I_t, at periods $t = 0$ and $t = 1$, produces and charges the price p_t at periods $t = 1$ and $t = 2$, and collects the used products at period $t = 3$.[1]

Specifically, at time 0 *M* invests under uncertainty. Manufacturer predicts that there are two demand states at time 1 due to the state of emotional customers. However, it has to make investment before demand is realized. This is because investment is subject to time-to-build (Garcia and Shen, 2010; Genc and Zaccour, 2013; Genc, 2017). The investment is

[1] The model could easily be extended to more than three periods because uncertainty unfolds after the second period and the model becomes deterministic (and tractable) thereafter.

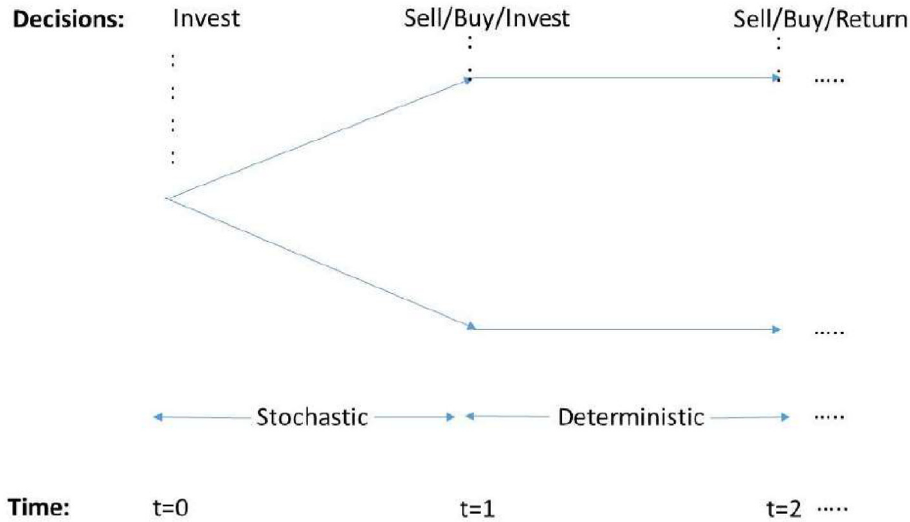

Fig. 1. Decisions over time.

realized and observed by all consumer types at time 1. At time 1, uncertainty unfolds and consumers buy the product according to their demand behavior. *M* can also invest at time 1 knowing that uncertainty is over for the following periods. It may choose to invest because emotions accumulate; some consumers respond to total investments, and thus future aggregate demand changes. At time 2, *M* meets the final period demand and collects the used and/or end-of-life products. We solve the model backward to follow the standard procedures applied in dynamic optimization.

2.1. Emotional consumers

Frijda (2000) notes that there is no universal definition of emotions because they involve so many phenomena. According to the green marketing literature, emotions linked to green products acts as a significant antecedent that affects consumers' responses, such as attitudes toward the investments advertisement, brand, purchase intention and positive word of mouth (Kim et al., 2020).

Our model of emotional consumers can cover either emotion types. Therefore, we define emotional consumers as the consumers who are attracted by the green products and think that green products help in preserving the environment for future generations. The emotional consumers evaluate and classify companies considering their contribution to the environment, and seek to pursue and sponsor green actions. A motivating example for the emotional consumers could be related to the drivers with feelings toward electric vehicles (EV) of Tesla (the manufacturer). Their demand for EV is a function of state of emotions. They form their emotions because of "green attributes" of the product for which consumers are happy, excited, and tender. They observe Tesla's green investments and product developments based on which they exhibit positive emotions. On the contrary, some consumers could be unsatisfied with Tesla's EV (investment and/or design) and might pose negative feelings toward it. For the sake of concreteness and clarity, we suggest to stick to positive emotions interpretation of the model from now on with Tesla example in mind.

Emotional consumers are denoted by $C1$ and their demand (at time t is q_{tE}) is a function of state of emotions (E_t). They buy the product based on manufacturer's green investments and are willing to pay the price set by *M*. They are then named emotional since they seek to improve and preserve the environment for the future generations independent of the price they are supposed to pay.

Specifically, demand for *M*'s product by emotional customers at time 1 is

$$q_{1E} = \alpha_{1E} + \beta_{1E} E_1 \tag{1}$$

where $\alpha_{1E}, \beta_{1E} \geq 0$, and emotions at time 1 are stochastic:

$$E_1 = \begin{cases} e_0 I_0 + \varepsilon_u & \text{with probability } \theta \\ e_0 I_0 + \varepsilon_d & \text{with probability } 1 - \theta \end{cases} \tag{2}$$

E_1 is an emotion function at time 1 which increases in green investment $I_0 \geq 0$ which is made at time 0 and is realized at time 1. That is, investment takes time and will be fully productive and observable in the next period. The marginal contribution of green investments on emotions is $e_0 \geq 0$. This structure allows us to consider a stochastic component for the emotional consumers, whose behavior are difficult to estimate (Kim et al., 2020) and cannot be treated as deterministic elements.

From *M*'s point of view, there will be two demand states of emotions at time 1. *M* does not know the distribution of θ but has a prediction of probabilities of these demand states. While *M* must invest under uncertainty at time 0, *M* could hire data brokers and/or marketing consultants to figure out the actual emotion drift which is ε. These firms do marketing research and advise the actual demand function of emotional customers at the end of period 1 and get paid. The money paid them by *M* is proportional to the actual emotion drift:

$$C(\varepsilon) = c_0 \varepsilon \tag{3}$$

where $c_0 \geq 0$. Alternatively, $C(\varepsilon)$ is the cost of removing uncertainty on emotions.

M has a choice to reinvest at the end of time 1 to meet the future demand at time 2. The emotional consumers respond to cumulative investment level at time 2. Specifically, their final period demand is

$$q_{2E} = \alpha_{2E} + \beta_{2E} E_2 \tag{4}$$

where $\alpha_{2E}, \beta_{2E} \geq 0$, and the emotion function evolves with time and is equal to

$$E_2 = e_0 I_0 + e_1 I_1 + \varepsilon \tag{5}$$

This is to say that emotions are with memory. The emotional consumers remember the past green investments and observe the new investments and then form their cumulative feelings toward the green product. The emotions that connect the past and the present experiences (i.e., green investments) are an element of extended consciousness (Tulving, 2002).

Note that "positive emotions" are captured through the coefficients e_0, $e_1 \geq 0$, and a positive drift (or shock) ε so that consumers show positive attitudes (happiness, satisfaction, excitement) towards the manufacturer's green investments, and the shock in emotion is also positive. The negativity of those parameters could form a definition of "negative emotions". This feature is novel as the literature mainly emphasizes "negative emotions" or "anticipated emotions" covering regret, anger, fear and disappointment (e.g., Loomes and Sugden, 1982; also see Loewenstein, 2000) which do not impact the current decisions and are only experienced after the purchase or usage of the product. On the contrary, in our formulation emotional consumers can form emotions before the purchase and/or right after *M*'s announcement of green investment projects. Loewenstein (2000) stresses the importance of positive and immediate emotions in decision making process.

2.2. Rational consumers

The second type of demand group is standard and is coined rational consumers (denoted *C*2). They are rational in the sense that they react to product price only. These consumers also observe green investments and acknowledge that the price already reflects the product specificity and quality. The rational consumers have very short term view and only think about themselves. Therefore, they simply decide to purchase according to the price, independent of the environmental impact of their purchasings and without considering the green efforts that the companies made. Therefore, they believe that firms adopt "green washing" actions.

Demand for *M*'s product by rational consumers is

$$q_{tP} = \alpha_{tP} - \beta_{tP} p_t \tag{6}$$

where $\alpha_{tP}, \beta_{tP} \geq 0$, p_t is the *M*'s price for the product sold over time $t = 1, 2$.

2.3. Conscious consumers

The third demand group is called green conscious, or simply, conscious consumers (denoted *C*3) who are conscious to both price and product greenness (Yang et al., 2019). Kim et al. (2020) suggest that firms' strategies must consider the effect of both rational and emotional consumers since the current literature focuses on one cluster only. Also, Albers-Miller and Stafford (1999) demonstrate how the estimation of emotional and rational consumer segments allow firms to better plan their strategies, choosing between service and advertising. Both emotional and rational types link to the existence of hidden and hybrid clusters, which we call conscious in this research. Therefore, the conscious consumers consider both rational and emotional elements when deciding whether to purchase a green product, which are hereby exemplified by pricing and green programs. Although they react to $M's$ green investments, they are not emotional as such their perceptions/feelings toward green product are instantaneous and do not accumulate over time. Following Liu and De Giovanni (2019), at a given time *t*, the consumers base their purchasing decisions on for a certain price and green investment level. Specifically, demand for *M*'s product by the conscious customers is

$$q_{tG} = \alpha_{tG} - \beta_{tG} p_t + \gamma G_t \tag{7}$$

where G_t refers to (green) consciousness at $t = 1, 2$ and is equal to

$$G_t = gI_{t-1} \quad \text{and} \quad \alpha_{tG}, \beta_{tG}, \gamma, g \geq 0. \tag{8}$$

The lag between investment and green consciousness is due to the fact that investment is subject to time-to-build, that is investment takes time to be productive. Their demand increases in green investment and decreases in price.

One may further justify the expressions in (7) and (8) applying a definition of consciousness. Consciousness is formed through the steps of attention, perception, and action (Funk et al., 2009a). That is, an attention leads to a perception which causes an action which finally leads to a conscious experience. Given this taxonomy, the expression in (8) implies that the manufacturer's green investment gets the "attention" of consumers who form their (green) "perception" of the product and then they take "action" as in expression (7) through which they decide whether to buy or not and/or how many green products to buy.

In the terminology of Damasio (1999), the consciousness function in (8) may refer to "core consciousness" rather than "extended consciousness". The former provides the feeling of "here and now" as such consumers become aware of the specific content (of the green investment). The latter, on the other hand, is also called higher order consciousness, attaches a past experience to a state of core consciousness. In this sense, emotion function in (5) which has memory and connects old experiences (i.e. green investments) with the new ones is related to extended consciousness. This observation distinguishes the emotion function in (5) from the consciousness function in (8), and therefore may provide a justification for studying the two separate consumer types.

2.4. The decision making model

M charges a uniform price over consumer groups. It does not exercise discriminatory prices over demand segments, e.g., due to resale opportunities. This is not a crucial assumption and it can be easily relaxed. *M*'s investment cost function at $t = 1, 2$ is quadratic (Genc and Zaccour, 2013), implying marginal cost of investment increases at an increasing rate (e.g., due to diseconomies of scale involving congestion and rising input costs):

$$F(I_t) = f\, I_t^2/2 \tag{9}$$

where $f \geq 0$. At the end of the planning horizon ($t = 2$), some consumers may return their used products and buy new ones. The return function is based on the cumulative investment level. It is equal to

$$r = d_0 - d_1(I_0 + I_1) \tag{10}$$

where $d_0, d_1 \geq 0$: the higher the aggregate investment, the lower the returns. This is because larger investment refers to better product and more positive emotions towards the product. This return function is in the vein of Genc and De Giovanni (2017, 2018) and De Giovanni and Zaccour (2019b) who argue that returns functions should include firm strategies such as price and quality. We assume that the green investments are "good" investments and that they increase the product quality as well.

M strives to maximize its expected discounted sum of profits to choose prices and investments:

$$\max_{p_t,\, I_t} E\Big[\sum_t \delta^t \Pi_t()\Big] \tag{11}$$

where the discount factor holds $0 < \delta \leq 1$ and $t = 0, 1, 2$. Specifically, at time 0 its payoff function is

$$\Pi_0() = -f\, I_0^2/2. \tag{12}$$

Investment is subject to uncertainty which stems from emotion states. At time 1, its expected profit function is

$$E[\Pi_1()] = \theta[(p_{1u} - c)q_{1u}] + (1-\theta)[(p_{1d} - c)q_{1d}] - f\, I_1^2/2 - c_0\varepsilon, \tag{13}$$

where $c \geq 0$ is the marginal cost of production, p_{1u} is the price if emotions unfold "high", p_{1d} is the price if emotions turn out "low".

With probability θ the total demand at time 1 is

$$q_{1u} = \alpha_{1E} + \beta_{1E}(e_0 I_0 + \varepsilon_u) + \alpha_{1P} - \beta_{1P} p_{1u} + \alpha_{1G} - \beta_{1G} p_{1u} + \gamma g I_0. \tag{14}$$

With probability $1-\theta$ the total demand at time 1 is

$$q_{1d} = \alpha_{1E} + \beta_{1E}(e_0 I_0 + \varepsilon_d) + \alpha_{1P} - \beta_{1P} p_{1d} + \alpha_{1G} - \beta_{1G} p_{1d} + \gamma g I_0. \tag{15}$$

At time 2, *M*'s profit function is

$$\Pi_2() = [(p_2 - c)q_2] + \Delta(d_0 - d_1(I_0 + I_1)), \tag{16}$$

where Δ is the marginal benefit obtained by collecting used products, and the total demand in the final period is

$$q_2 = \alpha_{2E} + \beta_{2E}(e_0 I_0 + e_1 I_1 + \varepsilon) + \alpha_{2P} - \beta_{2P} p_2 + \alpha_{2G} - \beta_{2G} p_2 + \gamma g I_1. \tag{17}$$

Consequently, the expected discounted total profit function to be maximized is

$$E[\Pi()] = -f\, I_0^2/2 + \delta\{\theta[(p_{1u} - c)(\alpha_{1E} + \beta_{1E}(e_0 I_0 + \varepsilon_u) + \alpha_{1P} - \beta_{1P} p_{1u} + \alpha_{1G} - \beta_{1G} p_{1u} + \gamma g I_0)] +$$
$$(1-\theta)[(p_{1d} - c)(\alpha_{1E} + \beta_{1E}(e_0 I_0 + \varepsilon_d) + \alpha_{1P} - \beta_{1P} p_{1d} + \alpha_{1G} - \beta_{1G} p_{1d} + \gamma g I_0)] - f\, I_1^2/2 - c_0 \varepsilon\}$$
$$\delta^2\{[(p_2 - c)(\alpha_{2E} + \beta_{2E}(e_0 I_0 + e_1 I_1 + \varepsilon) + \alpha_{2P} - \beta_{2P} p_2 + \alpha_{2G} - \beta_{2G} p_2 + \gamma g I_1)] + \Delta(d_0 - d_1(I_0 + I_1))\}$$

While the current model admits unique optimal strategies, it involves 26 parameters that render cumbersome pricing and investment strategies. For the sake of tractability, we suggest to normalize some coefficients. However, in numerical exercises section, we will remove those restrictions and vary these parameters at a time and examine their impacts on market outcomes.

Specifically, we will assume that the marginal cost of production is normalized to zero ($c = 0$), and slope terms for all periods are unity ($\beta_{1E} = 1 = \beta_{1P} = \beta_{1G}$ and $\beta_{2E} = 1 = \beta_{2P} = \beta_{2G}$). Furthermore, we assume that the slopes of emotion functions are unity ($e_0 = 1 = e_1$), and investment function and green-consciousness function parameters are unity ($f = 1 = g$). Assigning specific values to these parameters will not change the results qualitatively, but will lead to a tractable solution for optimal strategies. Also assume that demand intercepts are the same over time for a given consumer type. That is, market potential is identical over time. Notation-wise, $\alpha_{1E} = \alpha_{2E} \equiv \alpha_E$ and $\alpha_{1P} = \alpha_{2P} \equiv \alpha_P$ and $\alpha_{1G} = \alpha_{2G} \equiv \alpha_G$. Note that demand intercepts over consumer types are non-identical ($\alpha_E \neq \alpha_P \neq \alpha_G$) implying that consumer demands are different but are ordered and parallel to each other.

With this specification, the model will include 13 parameters and the expected profit function will boil down to

$$E[\Pi()] = -I_0^2/2 + \delta\{\theta[(p_{1u})(\alpha_E + (I_0 + \varepsilon_u) + \alpha_P - p_{1u} + \alpha_G - p_{1u} + \gamma I_0)] +$$
$$(1-\theta)[(p_{1d})(\alpha_E + (I_0 + \varepsilon_d) + \alpha_P - p_{1d} + \alpha_G - p_{1d} + \gamma I_0)] - I_1^2/2 - c_0 \varepsilon\}$$
$$\delta^2\{[(p_2)(\alpha_E + (I_0 + I_1 + \varepsilon) + \alpha_P - p_2 + \alpha_G - p_2 + \gamma I_1)] + \Delta(d_0 - d_1(I_0 + I_1))\}.$$

We tabulate the model notation encompassing 26 parameters, 9 variables and 5 strategies in Table 1.

3. Optimal strategies with all consumer types

We first intend to solve the complete model covering all consumer types. Later on we will assess the impact of each consumer group on *M*'s investment and pricing decisions.

Proposition 1. *When M serves to all consumer types, the investment and pricing strategies satisfy*

$I_0^* = \delta[\theta p_{1u}(1+\gamma) + (1-\theta) p_{1d}(1+\gamma)] + \delta^2[p_2 - \Delta d_1]$ and

$I_1^* = \delta[p_2(1+\gamma) - \Delta d_1]$, where the prices are

$$p_{1u} = \frac{\alpha_E + \alpha_P + \alpha_G + (I_0 + \varepsilon_u) + \gamma I_0}{4},$$

$$p_{1d} = \frac{\alpha_E + \alpha_P + \alpha_G + (I_0 + \varepsilon_d) + \gamma I_0}{4},$$

$$p_2 = \frac{\alpha_E + \alpha_P + \alpha_G + (I_0 + I_1 + \varepsilon) + \gamma I_1}{4}.$$

Proof. See the Appendix.

We denote the solution of these optimal strategies as superscript "*'' when all consumer types are served. Although the equilibrium conditions in Proposition 1 form a unique solution, a closed-form solution based purely on model parameters is cumbersome, lengthy and high degree of polynomials of the parameters. Therefore, to gain additional insights we will carry out numerical exercises based on critical model parameters.

Table 1
Model notation.

Players	Description
M	Firm M
$C1, C2, C3$	Consumer types
Parameters	
α_{tE}	demand intercept at time t by emotional consumers
β_{tE}	demand sensitivity to emotions at time t by emotional consumers
ε_u	variation in emotion at upstate
ε_d	variation in emotion at downstate
Θ	the probability of upstate emotion
e_t	emotion sensitivity to investment at time t
ε	actual drift in emotion
c_0	marginal payment to broker by M
α_{tP}	demand intercept at time t by price sensitive consumers
β_{tP}	demand sensitivity to price at time t by price sensitive consumers
F	slope term of investment function
α_{tG}	demand intercept at time t by green conscious consumers
β_{tG}	price sensitivity at time t by green conscious consumers
Γ	green consciousness sensitivity
g	sensitivity to investment by green conscious consumers
d_0	maximum used product return quantity
d_1	return sensitivity to aggregate investment
Δ	discount factor
Δ	marginal benefit per collection to M
Variables	
T	time
q_{tE}	demand by emotional customers at time t
E_t	emotion function at time t
I_t	green investment at time t
$F_t(I_t)$	investment expenditure at time t
p_t	uniform price charged to all consumers at time t
q_{tG}	demand by green conscious customers at time t
$G_t(I)$	green consciousness function at time t
q_{tP}	demand by price sensitive customers at time t
R	return function
C	competitive price of suppliers (S) per intermediate product
Π	total profit of M

In Proposition 1 we first observe that while the investment quantity which is made under uncertainty at time 0 is a function of all prices (p_{1u}, p_{1d}, p_2), the investment made at time 1 (after uncertainty unfolded) is only a function of time 2 price (p_2). This is because investment made at the outset will have an impact at all future demand states and prices. For the second period investment, the same reasoning applies because investment will be observable in the final period and *M* has to take into account of the final period price before it invests. These observations are parallel to the findings in investment under uncertainty literature (see Genc 2017 and references therein).

Second, the green investment strategies are directly functions of type 1 (emotional) and type 3 (conscious) customers' demand parameters (β_{1E}, β_{2E}, and γ). In fact, it is indirectly a function of all consumers' demand parameters through price functions (p_{1u}, p_{1u}, p_2). That is, although only emotional and conscious consumers are sensitive to *M*'s investments, type 2 (rational) consumers also implicitly respond to *M*'s investment. This is because investment impacts all prices in all demand states. Consequently, all consumer groups respond to *M*'s green investment choices.

Third, we observe that the optimal investment is equal to discounted expected price adjusted by sensitivities of emotions and consciousness to investment. Specifically, the initial investment is equal to discounted expected price which is $\delta[\theta p_{1u} + (1-\theta)p_{1d}]$ that is adjusted by the total investment sensitivity which is $(1+\gamma)$, plus discounted final period price p_2 adjusted by the total investment sensitivity $(1+\gamma)$, minus marginal benefit of collection Δ adjusted by return sensitivity to investment d_1. This rule also applies to the second period investment I_1 which is equal to discounted final period price p_2 adjusted by the sensitivity to investment $(1+\gamma)$ minus the marginal benefit of collections Δ adjusted by investment sensitivity to returns d_1.

Fourth, as defined in the used product return function, there is a negative relation between investments and used product returns. The higher the investments, the lower the product returns. That is, consumers buy and hold on to their products as long as possible when *M* invests and develops its product. As the return sensitivity to investment, measured by d_1 goes up *M*'s investments in both periods go down. Furthermore, investments and prices in all periods decrease in marginal benefit of used product collections measured by Δ. As marginal benefit of returns Δ increases, that is *M* makes use of returns for remanufacturing, it invests less in green product developments. On the other hand, if return sensitivity to investment d_1 were to decrease so that consumers would put little weight on green product developments and therefore would increase their returns, then *M* would interestingly step up its investments to exert more impact on both emotional and conscious consumers.

Finally, the prices increase in investment levels and vary with all demand parameters for all consumers. They also increase in emotion shocks ε_u, ε_d, and ε.

To obtain additional insights from the optimal strategies in Proposition 1, we carry out sensitivity analysis, reported in Appendix B, based on which we can now formulate the following claim:

Claim 1. *For a wide range of model parameters (the benchmark case), we find that* $p_2 > p_{1u} > p_{1d}$ *and* $I_0 > I_1$.

Accordingly, we find that the manufacturer invests more in green activity programs (GAP) in the beginning and less later. The initial investments have a twofold effect: on the one hand, they allow to appropriate soon of the returns' residual value and increase the demand quickly in the first period; on the other hand, there is a side effect embedded in the second period demand as the initial investments in GAP efforts also have an impact on the future. As consumers receive signals and information regarding the return policies and strategies that firms undertake in the first period, there is less pressure to continue to massively invest in the second period as consumers have observed the green programs and been attracted by the firm's green investment portfolio in the first period.

Further, the manufacturer adopts a penetration strategy: pricing less in the first period in order to capture the market and then pricing more in the second period. This is because green investments and emotions accumulate in parallel over time: the higher the green investments, the higher the emotions, and hence the higher the prices. Also, when the shock in emotions turns out to be high (i.e., $\varepsilon_u > \varepsilon_d$) all consumers have to pay a higher price. The emotional consumers are very sensitive to firm's green programs and they do not mind paying more; the preservation of the environment has a higher impact in their utility function.

To better understand the impact of each consumer type on investment and pricing strategies, we will run a numerical analysis on the most relevant parameters. Then we will solve the complete model by excluding a specific customer type to assess its effect on optimal decisions.

4. Numerical analysis

As the model solution covering all 26 parameters is non-tractable, we will run numerical analysis to gain additional insights about investment and pricing strategies. We will fix certain parameter values parallel to the ones in De Giovanni (2014), specifically:

$$\alpha_t = 1, \beta_t = 0.5, g = \gamma = 0.7, \Delta = 0.7, \theta = 0.5, \delta = 0.9, f = 1, c = 0.1,$$
$$c_0 = 0.3, \varepsilon = 0.5, d_0 = 0.7, \qquad d_1 = 0.1, e_0 = 0.5, e_1 = 0.5.$$

We will investigate the manufacturer's strategies and profits by pairs, considering their variations with respect to two parameters at a time. Interestingly, the shapes of strategies and profits with respect to the investigated parameters are characteristically identical. Therefore, we display only one figure that will apply to both strategies and profits from a qualitative point of view. Furthermore, we have chosen the region spaces to analyze according to the most interesting results that we obtain.

4.1. *Analysis in the* $(\gamma, \Delta) -$ *space*

Fig. 2 reports the characteristics of optimal profits in the $(\gamma, \Delta) -$ *space*, corresponding to green consciousness sensitivity and marginal benefit of used product collection, respectively. Accordingly, we observe that the firm's profits increase with the consumers' consciousness sensitivity (γ) as in accordance with the principle of green marketing emphasizing that consumers are socially and environmentally conscious; therefore, they are inclined to purchase from green companies only as they care about the environmental protection and preservation. Increasing γ has an important implication for the manufacturer's profits; thus, having the possibility to invest in a certain strategy to increase sales, firms should pursue green activity programs according to the consumers' green consciousness. We can also see that the manufacturer's profits increase in the residual value of returns, Δ, highlighting the fact that the products sold in the market should embed some durability such that they

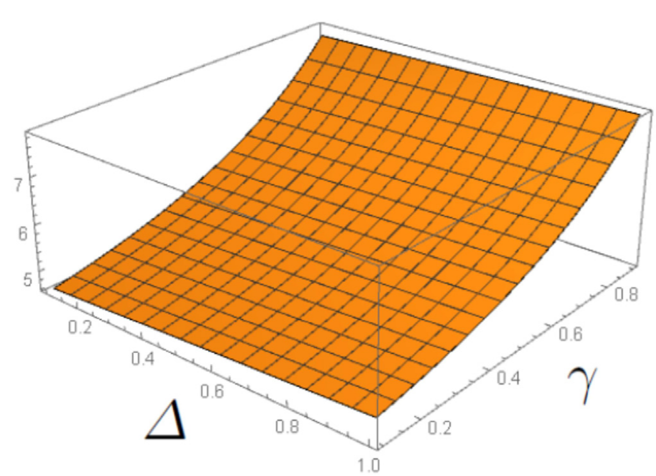

Fig. 2. Changes in profits according to marginal benefits for collection, Δ, and the green consumers' sensitivity, γ.

will still hold a value when they are returned. As we can see from Fig. 1, the impact of Δ on profits is not as high as the impact that γ has on profits. This highlights the idea that the manufacturer should care about its returns in order to show corporate responsibility. Nevertheless, the higher economic value is generated through creating new demand (i.e., through γ) rather than collecting from the environment (i.e., Δ). Consequently, firms should use the green activity programs across market segments as a lever to boost the demand as first target and increase the returns as second order target. Finally, we can see that the impact of Δ on profits is larger when the impact of γ is lower and vice verse. This signifies that a trade-off exists between economic rewards from returns and economic returns from new demand. Firms can use the market heterogeneity as a lever to manage this trade-off.

We find that the shape of Fig. 2 also applies to the strategies. The higher values of γ increases the impact of green investments, generally termed as green activity programs (GAP). Similarly, increasing values of Δ lead the manufacturer to invest more in GAP, highlighting the idea that the higher is the value of returns, the higher is the firm's willingness to do more to appropriate the returns' residual value. Simultaneously, the manufacturer also prices more, generating a compensating effect between GAP and pricing that is always in favor of higher profits. Therefore, green products become more expensive as consumers show high levels of green consciousness. Firms know that consumers care about green attributes and will purchase the products. Also, the high values of returns make the firm extremely interested in such a value.

From the sensitivity analysis displayed in Appendix B, we can formulate the following claim:

Claim 2. *Increasing values of Δ and γ strengthen the relationships proposed in* Claim 1.

When values of Δ and γ increase, the firm continues to adopt a penetration strategy, pricing more in period 2 than in period 1. Also, firms should continue to invest more in GAP during the first period as they can immediately act on the consumers' willingness to return, boost the demand and increase the value of reverse logistics activities.

4.2. Analysis in the $(e_0, e_1) -$ space

In this subsection we concentrate on the analysis of the $(e_0, e_1)-$ *space*, referring to the sensitivity of emotions to green investments as well as to the evolution of stock of emotions that accumulate over the planning horizon. Emotions fully depend on the GAP efforts invested in each period, which substantially contribute to the sales. Emotional consumers accumulate emotions regarding the use of green products and their importance for the environment according to the green investment efforts developed in both periods. According to Fig. 3, firms seeking to increase the consumers' green consciousness should strategically set the GAP strategies in both periods to perform higher sales and profits.

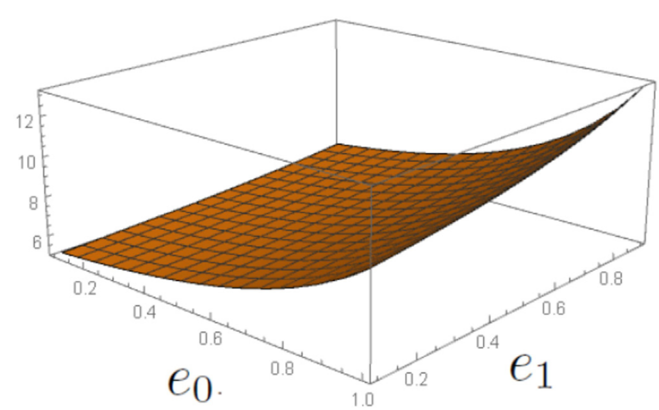

Fig. 3. Changes in profits according to the sensitivity to emotions, e_t.

Interestingly there is a certain correlation between the GAP efforts in different periods. First, we notice that the impact of I_0 on the accumulated stock is independent of the other strategy. That is, the contribution that I_0 provides to the stock of emotions increases according to its marginal contribution to that stock but its overall impact does not depend on the amplitude of e_1. In particular, if e_1 takes high values or low values, the contribution of I_0 on the emotions stock increases according to e_0 with the same rate. Consequently, firms investing in the first period in GAP efforts should only focus on setting an optimal strategy, independent of what will happen in the future. This highlights the idea that consumers have memory and their stock of emotions is accumulated starting from the initial period and remains with them forever. So, once the stock is accumulated, firms are sure that emotional consumers will remain even in the future.

Differently, the impact of I_1 on the accumulation of green emotions very much depends on the amplitude of e_0. When e_0 takes low values, it signifies that consumers are reluctant in accumulating stock of emotions in the first period. Since they have memory, this is reflected in a low attitude of accumulating that stock over time. In sum, if consumers were not emotional in the first period, they would become more conscious in the future with a very negligible increment. This informs us on the difficulties to convince consumers who are not emotional to care more about the environment and warns firms on the strategies to be undertaken in order to generate extended consciousness on consumers. In the other case, when the consumers' sensitivity to emotions in the first period is high (i.e., high e_0), a GAP strategy aiming at increasing the stock of emotions will be extremely effective. We can see that I_0 has an increasing contribution on the stock according to e_1 and as such this contribution is substantial when e_0 is high. So, consumers who are emotional in the first period will continue to be emotional also in the second period and could be attracting more consumers through, e.g., by the word-of-mouth effect. Firms that estimate higher consumer emotions according to the GAP efforts should insist investing in this strategy to improve the profits through the stock of emotions.

We experience an interesting increase of both pricing and GAP efforts when consumers are highly sensitive to I_0 and I_1 in accumulation of their emotions. Note that emotional consumers disregard the price when they make their purchasing decisions. Therefore, their utility is GAP-based only and the accumulation of emotions plays a crucial role for reaching some levels of sales. Indeed, since the GAP efforts are the only strategy through which consumers can be attracted into the firm's portfolio and the sales be increased, the manufacturer should devote a substantial attention to the GAP investment by carefully analyzing the trade-off emerging from the GAP investment costs and their benefits to the demand.

Based on the sensitivity analysis displayed in Appendix B, we put forward the following findings.

Proposition 2. *When e_0 takes high values, firms move from a penetration strategy to a skimming strategy for highly emotional consumers, implying $p_{1d} < p_2 < p_{1u}$. On the other hand, the GAP strategies remain at the benchmark, i.e., $I_0 > I_1$.*

When the contribution of GAP strategy in the first period increases substantially, the manufacturer puts a lot of efforts in the first period to exploit emotions. In addition, the manufacturer knows that the accumulated stock of emotions can be extremely high in the first period, thus the high stock justifies a strategic move from a penetration to a skimming pricing strategy in which the manufacturer prices high in the first period and low in the second period. This finding has important implications for the pricing strategy. When adopting a penetration pricing strategy, firms charge low price in the first period to attract as many consumers are possible, fidelize them and keep them in their portfolio also in the future periods. When adopting a skimming pricing strategy, firms charge a high price in the first period and decrease it in the future period. In general, a skimming pricing strategy is applied any time the company release new versions from one period to another; hence, they decrease the price of the old versions in the successive periods. In our setting, firms should continue to adopt a penetration strategy for low emotional consumers and a skimming strategy for high emotional consumers. This result is driven by the idea that since a lot of stock are accumulated in the first period, the investments in GAP efforts can be reduced in the second period. The reduction of these investments should then be compensated by a reduction in price. This allows firms to guarantee a certain level of sales in the second period, even without spending massively in GAP efforts.

Proposition 3. *When e_1 takes high values, firms should continue to adopt a penetration strategy, i.e., $p_2 > p_{1u} > p_{1d}$. However, the GAP strategies reverse with respect to the benchmark, i.e., $I_0 < I_1$.*

When the contribution of the GAP strategy in the second period becomes very relevant, firms should invert their behavior with respect to their investments in green efforts, spending more in the second period than in the first period. This is rather intuitive as they prefer to put more efforts in a moment when consumers are more sensitive to GAP efforts. Notice that firms' pricing and GAP strategies are very much aligned at this stage. In particular, the pricing strategy is fully driven by the consumers' emotion. When the accumulated emotion is high, firms also price high. When the accumulated stock is low, the price is also low. In this regard, the GAP efforts are mainly used as a marketing tool to attract more consumers, increasing the stock of emotions and making sure that the compensating effect between pricing and green efforts ends with a positive sign.

4.3. Analysis in the $(f, g) - space$

This subsection analyzes the firm's strategies and profits in the $(f,g) - space$, corresponding to rate of marginal investment cost and consciousness sensitivity to investment, respectively. This space is of considerable importance for firms as it directly links to the impact of GAP efforts in the firm's objective function in terms of costs as well as its positive impact on sales through the green consciousness stock. Fig. 4 displays the manufacturer's profits with relations to these two effects. Indeed, as expected, the profits increase in the consumers' sensitivity to green efforts and the related stock, while they decrease according to the marginal cost associated to the green investments. Nevertheless, we aim at highlighting the perfect correlation that exists between the two ingredients. When the marginal contribution of GAP on the stock of emotion is low, the negative impact of GAP efforts on the firm's objective function is negligible. The manufacturer will not decide according to the cost of GAP investments as its profits are not substantially hurt by such a strategy. Conversely, when the contribution of GAP efforts on the stock of green consciousness is high, increasing the GAP efforts is very severe as the profits go down considerably. Consequently, when the marginal contribution of GAP on the consumers' consciousness is high, GAP efforts form a very challenging strategy from a cost point of view. Instead, when consumers' green consciousness stock does not change substantially according to the GAP efforts, the cost impact is marginal. In such a case, the GAP strategy is not interesting for the manufacturer, who should look at other ways to become greener and increase profits.

As Fig. 4 also explains the changes of the strategies in the $(f, g) - space$, one can see that as the GAP strategy becomes more expensive and less effective, firms need to search for alternative ways to expand the business by adjusting the price for all types of consumers at the same time. In such a case, consumer emotions play a minor role while consumer rationality is the key aspect to create future business opportunity.

In Appendix B, we can observe the sensitivity of strategies and profits with respect to f and g and reach the following findings:

Proposition 4. *When f takes high values, the manufacturer moves from a penetration strategy to a skimming strategy for highly conscious consumers, implying $p_{1d} < p_2 < p_{1u}$. Nevertheless, the GAP strategies remain at the benchmark, i.e., $I_0 > I_1$.*

Proposition 5. *When g takes high values, the manufacturer continues to adopt a penetration strategy aligning their strategies at the benchmark case as in Claim 1.*

These two results allow us to derive interesting insights on the firm behavior. First, independent of the GAP's impact on demand, firms should always adopt a penetration strategy; thus, fixing a lower price in the first period to attract consumers into their portfolio and then charging a high price in the future. At the same time, higher future investments in GAP efforts allow firms to justify higher price. Second, firms should evaluate the amplitude of GAP investments in their objective function before deciding the strategy to pursue. When the marginal impact of GAP strategies on the profits is considerable, firms should move from a penetration to a skimming strategy for high conscious consumers. In fact, firms need to extrapolate some additional economic value from these consumers due to the high negative impact of GAP efforts on their payoffs. At the same time, a penetration strategy should be pursued for low conscious consumers, for whom the investments in GAP do not result in higher willingness to purchase. Finally, penetration and skimming policies can co-exist in our framework as the related pricing strategies are largely linked to the consumer type that firms target.

4.4. Analysis in the $(\beta_{2G}, \beta_{1E}) - space$

In this part, we analyze the impact of β_{2G} and β_{1E}, symbolizing price sensitivity of conscious consumers in period 2 and demand sensitivity of emotional consumers in period 1, on the firm's strategies and profits. Different than the other demand parameters that give rise to intuitive

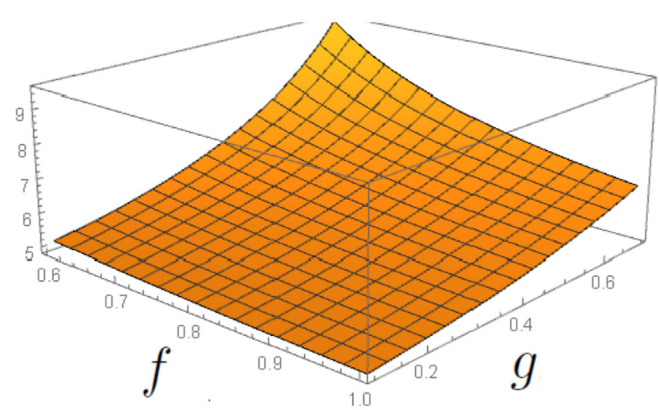

Fig. 4. Changes in profits according to the investments efficiency, f, and the green conscious consumers' sensitivity, g.

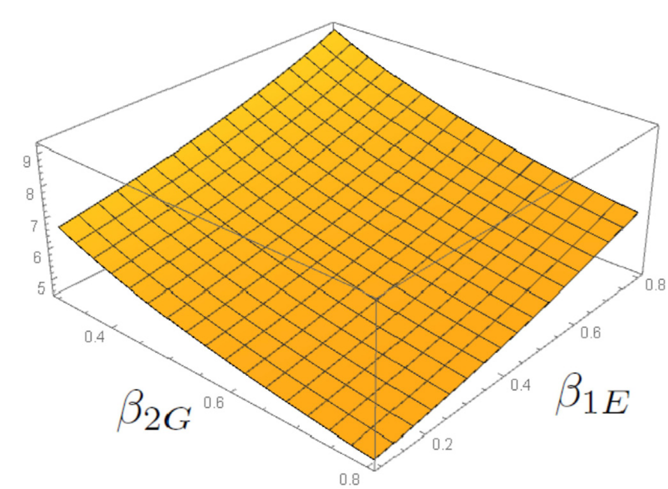

Fig. 5. Changes in profits according to the sensitivity to emotions, β_{tE}.

outcomes, these two parameters allow us to derive some strategies for the firm. From Fig. 5, we can see that the impact of the two parameters on the firm's strategies and profits follows the classical result in economics. That is, higher consumers' sensitivity to price leads to lower profits, while higher consumers' sensitivity to green programs leads to higher profits. If the manufacturer lives in an ideal setting, low β_{2G} and high β_{1E}, it will obtain the highest profit. We can then experience two interesting settings: when β_{2G} and β_{1E} are both very low and when β_{2G} and β_{1E} are both very high. In these cases, the manufacturer is indifferent between living in a world in which conscious consumers react quickly to any price hike while emotional consumers are very sensitive to green efforts, and living in a world in which both conscious and emotional consumers play a marginal role. When emotional consumers become more emotional, investing more in green programs boosts the sales and justifies the price increase. We experience a general trade-off between pricing and green efforts that can be challenging to settle.

When emotional consumers cover a marginal piece in the market, firms should abandon the idea of doing green efforts so as to boost sales. Rather, they should focus on using green efforts to only fulfill any environmental and legislative constraints.

In addition, in Appendix B we can see the sensitivity of strategies and profits with respect to β_{2G} and β_{1E} and derive the following finding:

Proposition 6. *When β_{2G} and β_{1E} take high values, the manufacturer moves from a penetration strategy to a skimming strategy for all types of behavioral consumers so that $p_2 < p_{1d} < p_{1u}$ holds. Furthermore, the GAP strategies remain at the benchmark, i.e., $I_0 > I_1$.*

Interestingly, the case of increasing β_{2G} and β_{1E} is the only situation when the manufacturer fully changes his strategies with respect to the entire market of behavioral consumers by adopting a skimming pricing strategy. This is due to the fact that when these parameter values increase, the GAP investments either decrease or they only increase marginally. As a consequence, emotional consumers lose some of their memory (of stock of emotions) and the manufacturer focuses more on rational and conscious consumers.

5. The impact of emotional consumers

In the following analysis we examine the impact of emotional consumers on the performance by supposing what if these consumers would not exist or *M* would not serve to them just because they are costly and demanding continuous green product developments.

Proposition 7. *If there would not be emotional consumers or M would ignore their behavior and demand (that is $\alpha_{1E} = \alpha_{2E} = 0 = \beta_{1E} = \beta_{2E}$ and $\theta = 1$), then the optimal strategies would satisfy the following. The investments would be*

$$I_0^E = \frac{\delta[\gamma(\alpha_P + \alpha_G) - 4\delta\Delta d_1]}{4 - \delta\gamma^2} \text{ and } I_1^E = \frac{\delta[\gamma(\alpha_P + \alpha_G) - 4\Delta d_1]}{4 - \delta\gamma^2}. \text{ The prices would hold}$$

$$p_1^E = \frac{\alpha_P + \alpha_G - \delta^2\gamma\Delta d_1}{4 - \delta\gamma^2} \text{ and } p_2^E = \frac{\alpha_P + \alpha_G - \delta\gamma\Delta d_1}{4 - \delta\gamma^2}.$$

Proof. See the Appendix

We denote optimal strategies in the absence of emotional consumers as superscript "*E*". The characteristics of these investment and pricing strategies show some differences than those of Proposition 1. Specifically, the key difference between investments I_0^E and I_1^E is that while the former depends on time 1 price sensitivities the latter depends on time 2 price sensitivities. However, when emotional consumers were in play, the initial investment in Proposition 1 was a function of demand slopes in all states/periods. The main reason for this result is that emotions were accumulated under the conditions of Proposition 1. However, in Proposition 2 the state vector does not evolve.

Investments are functions of demand parameters of consumer types. This result is parallel to the one in Proposition 1. That is, although green conscious consumers are sensitive to *M*'s investments as their demand is sensitive to investments, the rational consumers (type 2) also play a critical role for *M*'s investment decision.

The optimal investment rule is similar to the one in Proposition 1: *M* will base its investment on discounted price adjusted to green consciousness sensitivity to investment. Furthermore, *M*'s investments in both periods decrease in return sensitivity to investment measured by d_1, and decrease in marginal benefit of used product collections measured by Δ. Finally, the product price increases in investment level and increases in demand intercepts of all existing consumers for a given period.

In the next result, we compare the market outcomes with and without emotional consumers.

Corollary 1. *The existence of emotional consumers raises prices, investments, and profits. Alternatively, the manufacturer should serve emotional consumers to be able to further increase its profits, although it will face uncertainty over emotions and incur costly investments. Notation-wise, $p_2^* > p_2^E$ and $I_1^* > I_1^E$ and $E[p_1^*] > p_1^E$ and $I_0^* > I_0^E$ and $E[\Pi^*] > \Pi^E$ for any admissible emotion shocks ε_u , $\varepsilon_d \geq 0$.*

M charges monopoly price to all consumers whether emotional consumers are served or not. With addition of emotional consumers, the total demand curve will shift up and therefore the monopoly price charged to type 2 and type 3 consumers goes up when emotional consumers are also present. The profit comparison is a direct result of prices because the aggregate demand curve that *M* faces will go up by the inclusion of emotional consumers. Consequently, *M*'s profit when all consumers are served will be higher than its profit when emotional consumers are excluded.

6. The impact of conscious consumers

The main difference between emotional consumers (type 1) and conscious consumers (type 3) is that while the latter responds to price the former bases their demand only on emotions. Furthermore, while the former responds to aggregate level of green investments to form emotions, the latter only responds to the most recent green investment to form green consciousness. Alternatively, while the former is with memory the latter is memoryless. That is, because the emotional consumers map total green investments to emotions, their behavior evolves over time. However, consciousness only changes with respect to green investment made at a given time.

In the following proposition we examine the impact of conscious consumers on the firm performance by supposing what if these consumers would not exist or *M* would ignore them.

Proposition 8. *If there would not be conscious consumers or M would ignore their behavior (that is $\alpha_{1G} = \alpha_{2G} = 0 = \beta_{1G} = \beta_{2G}$ and $\gamma = 0$), and only serve both emotional and rational consumers then the optimal strategies would satisfy the following. The investments would hold*

$$I_0^C = \frac{\delta(4-\delta)[\alpha_{EP}+\overline{\varepsilon}] + 4\delta^2[\alpha_{EP}+\varepsilon-4\Delta d_1]}{16-8\delta-3\delta^2} \text{ and}$$

$$I_1^C = \frac{\delta[(\alpha_{EP}+\overline{\varepsilon})(4\delta-\delta^2) + (\alpha_{EP}+\varepsilon-4\Delta d_1)(16-8\delta+\delta^2)]}{(4-\delta)(16-8\delta-3\delta^2)}.$$ The prices would hold

$$p_{1d}^C = \frac{[\alpha_{EP}+\varepsilon_d](16-8\delta-3\delta^2) + [\alpha_{EP}+\overline{\varepsilon}]\delta(4-\delta) + [\alpha_{EP}+\varepsilon-4\Delta d_1]4\delta^2}{4(16-8\delta-3\delta^2)}, \text{ and}$$

$$p_2^C = \frac{[\alpha_{EP}+\varepsilon](64-32\delta+4\delta^2) + [\alpha_{EP}+\overline{\varepsilon}]\delta(16-4\delta) - 4\delta\Delta d_1(16+8\delta-3\delta^2)}{4(4-\delta)(16-8\delta-3\delta^2)},$$ where $\overline{\varepsilon} = \theta\varepsilon_u + (1-\theta)\varepsilon_d$

and $\alpha_{EP} = \alpha_E + \alpha_P$.

Proof. See the Appendix

Above we denote optimal strategies in the absence of conscious consumers as superscript "*C*".

Both investment functions show similar characteristics while the last period investment is heavily discounted. Investments are functions of demand parameters of both emotional and rational consumer types. This result is parallel to the one in Proposition 1.

The optimal investment rule is also similar to the one in Proposition 1: *M* will base its investment on discounted price adjusted to the sensitivity of emotions to investment. Furthermore, *M*'s investments in both periods decrease in return sensitivity to investment measured by d_1, and decrease in marginal benefit of used product collections measured by Δ. Finally, although the product price increases in investment level, the final period price (p_2) is a function of cumulative investment ($I_0 + I_1$) the previous period prices (p_{1u}, p_{1d}) only change with the initial period investment I_0 (see the proof in the Appendix).

Interestingly, all investment and pricing strategies depend on the amount of expected emotional shocks ε_u and ε_d as well as actual shock ε. Even the investment made at time 0 will be affected by the actual realization of the shock that will be materialized at the end of time 1. Moreover, all of these shocks raise the investments and prices. In addition, demand intercepts α_E and α_P also contribute to price and investment hikes in all periods.

In the next result we compare optimal strategies with and without green conscious consumers.

Corollary 2. *The existence of green conscious consumers raises prices, investments, and profits. Alternatively, the manufacturer should serve to green conscious consumers to be able to further increase its profits. Notation-wise,* $p_2^* > p_2^C$ *and* $I_1^* > I_1^C$ *and* $p_{1u}^* > p_{1u}^C$ *and* $p_{1d}^* > p_{1d}^C$ *and* $I_0^* > I_0^C$ *and* $E[\Pi^*] > \Pi^C$ *for all emotion shocks* ε_u , ε_d, $\varepsilon \geq 0$.

The proof of this Corollary is in the same vein of that of Corollary 1. By serving one more consumer group, *M*'s demand will shift up which will cause *M* to increase its prices and investment levels. This will enhance overall profitability.

7. The impact of rational consumers

As opposed to other consumer types, rational consumers who are price sensitive only and are not concerned with the environmental issues. They are rational in the sense that they only respond to product price. This is the consumer type mainly examined in the literature. However, we will show that the behavior of this consumer type will interestingly shape *M*'s green investment decisions and impact the environmental performance.

In the following proposition we characterize optimal price and investment strategies in the absence of rational consumers. This way we will be able to compare the performance when all consumer groups are covered versus when only price sensitive consumers are excluded in the market.

Proposition 9. *In the absence of rational consumers (that is* $\alpha_{1P} = \alpha_{2P} = 0 = \beta_{1P} = \beta_{2P}$ *), the optimal strategies are as follows. The investments hold*

$$I_0^R = \frac{\delta(2-\delta(1+\gamma)^2)(1+\gamma)[\alpha_{EG}+\overline{\varepsilon}] + 2\delta^2[\alpha_{EG}+\varepsilon-2\Delta d_1+\delta\gamma(1+\gamma)\Delta d_1]}{4-\delta(1+\gamma)^2(4-\delta(1+\gamma)^2)-2\delta^2}$$

$$I_1^R = \frac{\delta[(\alpha_{EG}+\varepsilon+I_0^R)(1+\gamma)-2\Delta d_1]}{2-\delta(1+\gamma)^2}.$$ The prices satisfy

$$p_{1u}^R = \frac{\alpha_{EG}+(1+\gamma)I_0^R+\varepsilon_u}{2},$$

$$p_{1d}^R = \frac{\alpha_{EG}+(1+\gamma)I_0^R+\varepsilon_d}{2}, \text{ and}$$

$$p_2^R = \frac{\alpha_{EG}+I_0^R+(1+\gamma)I_1^R+\varepsilon}{2},$$ where $\overline{\varepsilon} = \theta\varepsilon_u + (1-\theta)\varepsilon_d$ and $\alpha_{EG} = \alpha_E + \alpha_P$.

Proof. See the Appendix

We denote optimal strategies in the absence of price sensitive consumers as superscript "*R*".

The optimal investment rule is that *M* will base its investment on discounted price adjusted to the sensitivity of emotions and consciousness to investment (which is $1+\gamma$) less marginal benefit of collection adjusted by return sensitivity to investment (which is Δd_1). *M* will reduce its investments if return sensitivity to investment measured by d_1 and marginal benefit of used product collections measured by Δ increase. Also, prices increase in investment in every period: while the final period price (p_2) increases in aggregate investment ($I_0 + I_1$) the period 1 prices (p_{1u}, p_{1d}) increase in initial period investment I_0. Furthermore, higher

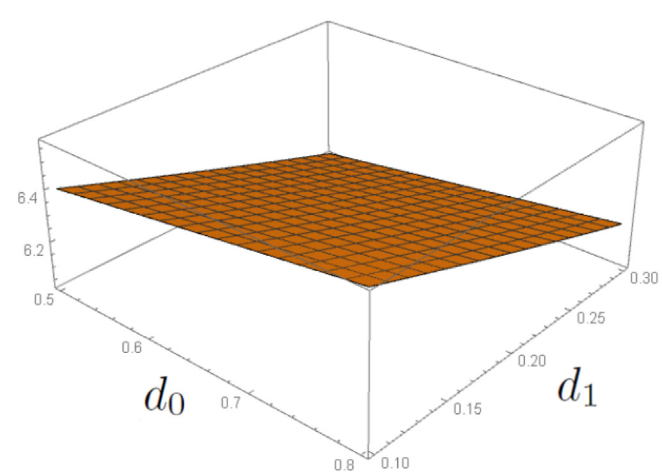

Fig. 6. Changes in profits according to maximum used quantity, d_0, and the return sensitivity, d_1.

investment in the initial period will yield higher investment in the following period. That is, $\partial I_1/\partial I_0 > 0$.

Also, green investment and pricing strategies depend on the amount of expected emotional shocks ε_u and ε_d as well as actual shock ε. All of these shocks will increase the green investments and prices. Furthermore, the existence of price sensitive consumers raises prices, investments, and profits. That is, *M* should take into account of all consumer groups whose aggregate demand will lead to higher investments and profits.

8. The impact of returns

This section aims to quantify the number of used product returns associated with consumer groups. As defined in equation (10), the returns are inversely related to total investments. Then the following question arises: which combination of consumer groups leads to higher product returns? Based on the above results, we learn that when all consumer groups are served by the manufacturer, the aggregate investment is the highest (Corollaries 1 and 2). Therefore, the number of returns will obtain its minimum when all consumer groups are served (Proposition 1).

What remains to be addressed is what other combinations of consumers lead to the next lowest returns. To address this question we have to compare the total investments under Propositions 2-4. Because demand functions of emotional and conscious consumers are mainly based on the level of investments, and demand (and profit) increases in green investment, the next highest total investment will be observed under Proposition 4 under which all emotional and conscious consumers are served. This implies that the second lowest number of returns will occur with consideration of emotional and green conscious consumers. Using the same reasoning, the third highest optimal level of investments will happen with the combination of emotional and price sensitive consumers (Proposition 3). This is when green conscious consumers are excluded. Finally, the lowest number of total investment will be realized when emotional consumers are excluded (Proposition 2), and hence the highest used product returns. The reason for this result is that demand function of emotional consumers is purely based on accumulation of green investments. Consequently, we obtain the following result.

Corollary 3. *The lowest level of used product returns will be observed when all consumer groups are served. The highest level of returns will occur when emotional consumers are excluded from the market. In particular, the ranking of returns which is purely based on ranking on total green investments and is follows*: $r^E > r^C > r^R > r^*$.

The formal proof of this Corollary stems from comparison of total investment in the propositions. For the sake of briefness we skip the proof, because it relies on the fact that the comparison of the total investments in the Propositions will lead to the following ranking: $I_0^E + I_1^E < I_0^C + I_1^C < I_0^R + I_0^R < I_0^* + I_1^*$.

Fig. 6 displays the changes in firm profits according to the return parameters. Indeed, when we would draw a figure for the strategies, we would get a strict line as all strategies are d_0-independent. In terms of profits, we get the intuitive result that higher passive returns lead to higher profits. However, increasing values of d_1 leads to a considerable reduction in manufacturer profits. Then, although investing in GAP efforts encourages emotional consumers to purchase more, the lower returns that the firm obtains can be an important deterrent of being "too much green". When the impact of d_1 is too detrimental, investing in GAP efforts may not be an effective lever to develop business. Firms should then look at other alternatives such as lowering rebates or trade-in value so as to reduce the impact of return sensitivity to green investments (d_1).

9. Conclusions

This paper investigates the optimal green investments and pricing strategies when the market is composed of different demand segments. One of the novelties of this paper is the explicit consideration of behavioral consumers who are emotional and environmentally conscious about green products. Emotional consumers form their purchasing decisions by only evaluating the firm's contribution to the environment, which is exemplified by the green efforts and the related emotions accumulated over time. Interestingly, these consumers are not making any price evaluation, being driven by green feelings. On the other hand, conscious consumers are driven by both the green efforts and the pricing strategies; therefore, they evaluate the overall convenience of purchasing green products. Finally, some consumers are fully rational as they only evaluate the price before making their purchasing decisions. We investigate the effect of each consumer type on firm strategies (namely, price and green efforts) and profits in a dynamic setting where consumer behaviors (through emotions and consciousness) and producer behavior (through green activity programs) evolve over time.

We show that when emotional consumers exhibit uncertainty about their emotions, the manufacturer is challenged by the complexity of its decisions. Nevertheless, the existence of emotional consumers allows the firm to increase its profits through ad-hoc pricing and green efforts strategies. Our results show that the firm in general should implement a penetration strategy, by setting low prices in the beginning and high prices in the future. At the first, the firm should focus on attracting consumers into their portfolio by increasing the GAP efforts and charging low prices. Later on, GAP investments are still possible but their impact becomes less important over time. Because emotional consumers have memory, the past investments in green efforts will entail delayed effects. Increased emotions will push the firm to invest more. We determine the conditions under which the firm should move from a penetration to a skimming strategy for high emotional consumers. Those are the consumers that are attracted by green consciousness and will remain loyal to the firm in the long term. Even when the firm increases the price, emotional consumers will still continue to purchase the product. Therefore, although a certain level of uncertainty exists and uncertainty is costly, the firm should look into the possibility to fully satisfy those consumers. When the effect of green investments on the accumulation of emotions is high in the long term, the firm should focus its attention on the short term GAP efforts so as to elevate the emotions. Finally, there is only one case, involving low emotional consumers, in which the firm will shift from a penetration to a skimming pricing strategy. This happens when the emotional sensitivity to product demand is high and/or when the consciousness sensitivity to price is high. In these circumstances, the manufacturer should go with skimming strategy for all behavioral consumers. Interestingly, our findings show that the green efforts discourage returns, and this can be very detrimental for the firm profitability. Therefore, the firm should look at the overall trade-offs entailed by pricing and green effort strategies when emotional consumers are present in the marketplace as the impact of returns can be substantial on these strategies. Accordingly, we can leave the following managerial prescriptions:

- firms should keep a close look to emotional consumers, who have a much higher impact than all other segments in determining the firms' strategies and profits;
- in general, a penetration pricing strategy is suggested when the market is divided into segments. However, when the emotional consumers consist of the largest segment, a skimming pricing strategy should be adopted.
- the presence of market segment amplifies the trade-off between environmental and economic performance since investments in green activities discourage returns and decrease profits. Firms should then balance this trade-off by moving from a penetration to a skimming pricing strategy accordingly.

This research is not free of limitations. Some assumptions could be relaxed to extend the paper in a number of directions. We have purposely focused on a single manufacturer to be able to examine the role of behavioral consumers. One could employ additional firms within the same tier and then analyze the competition in the presence of emotional consumers. One could also extend the current model to incorporate a sophisticated vertical relations model involving a closed-loop supply chain in which retailers and collectors can also interact. In that environment, it would be interesting to see how behavioral consumers would impact the vertical relations and profit distribution among the chain members. In addition, one could include operational controls such as quality, R&D and service, which could have an impact on the perceived value of each product, especially for conscious consumers. Other stochastic elements can be taken into account related to the market potential and the returns. Finally, it would be interesting to verify the results of this research empirically.

Declaration of competing interest

I, the underlined, Pietro De Giovanni, Associate Professor at LUISS University, Italy, declare my interest in submitting and publishing this paper in Cleaner and Responsible Consumption. I declare that I have no conflict of interest with the board of Cleaner and Responsible Consumption. I declare that this work is original and it is not under submission in order journals. I declare that we did not use confidential information or data in writing this paper. I declare that this paper respect all human rights and conditions.

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Appendix A. Proofs

Proof of Proposition 1

$$E\Pi = -f\,I_0^2/2 + \delta\{\theta[(p_{1u}-c)(\alpha_{1E}+\beta_{1E}(e_0I_0+\varepsilon_u)+\alpha_{1P}-\beta_{1P}p_{1u}+\alpha_{1G}-\beta_{1G}p_{1u}+\gamma gI_0)]+$$
$$(1-\theta)[(p_{1d}-c)(\alpha_{1E}+\beta_{1E}(e_0I_0+\varepsilon_d)+\alpha_{1P}-\beta_{1P}p_{1d}+\alpha_{1G}-\beta_{1G}p_{1d}+\gamma gI_0)]-f\,I_1^2/2-c_0\varepsilon\}+$$
$$\delta^2\{[(p_2-c)(\alpha_{2E}+\beta_{2E}(e_0I_0+e_1I_1+\varepsilon)+\alpha_{2P}-\beta_{2P}p_2+\alpha_{2G}-\beta_{2G}p_2+\gamma gI_1)]+\Delta(d_0-d_1(I_0+I_1))\}$$

The derivative of this expected discounted profit function with respect to time zero investment is $\frac{\partial E\Pi}{\partial I_0} = -f\,I_0+\delta[\theta(p_{1u}-c)(\beta_{1E}e_1+\gamma g)+(1-\theta)(p_{1d}-c)(\beta_{1E}e_1+\gamma g)]+\delta^2[(p_2-c)(\beta_{2E}e_1)-\Delta d_1]=0$. This leads to

$$I_0 = \frac{\delta[\theta(p_{1u}-c)(\beta_{1E}e_1+\gamma g)+(1-\theta)(p_{1d}-c)(\beta_{1E}e_1+\gamma g)]+\delta^2[(p_2-c)(\beta_{2E}e_1)-\Delta d_1]}{f}$$

The derivative of the expected discounted profit function of M with respect to time one investment is $\frac{\partial E\Pi}{\partial I_1} = -\delta f\,I_1+\delta^2[(p_2-c)(\beta_{2E}e_1+\gamma g)-\Delta d_1]=0$, which results in

$$I_1 = \frac{\delta[(p_2-c)(\beta_{2E}e_1+\gamma g)-\Delta d_1]}{f}$$

Similarly, the first order conditions with respect to prices are the following.
$\frac{\partial E\Pi}{\partial p_{1u}} = \delta[\theta(\alpha_{1E}+\beta_{1E}(e_0I_0+\varepsilon_u)+\alpha_{1P}-2\beta_{1P}p_{1u}+\alpha_{1G}-2\beta_{1G}p_{1u}+c(\beta_{1P}+\beta_{1G})+\gamma gI_0)]=0$. This leads to

$$p_{1u} = \frac{\alpha_{1E}+\beta_{1E}(e_0I_0+\varepsilon_u)+\alpha_{1P}+\alpha_{1G}+c(\beta_{1P}+\beta_{1G})+\gamma gI_0}{2(\beta_{1P}+\beta_{1G})}.$$

$\frac{\partial E\Pi}{\partial p_{1d}} = \delta[(1-\theta)(\alpha_{1E}+\beta_{1E}(e_0I_0+\varepsilon_d)+\alpha_{1P}-2\beta_{1P}p_{1d}+\alpha_{1G}-2\beta_{1G}p_{1d}+c(\beta_{1P}+\beta_{1G})+\gamma gI_0)]=0$. This leads to

$$p_{1d} = \frac{\alpha_{1E}+\beta_{1E}(e_0I_0+\varepsilon_d)+\alpha_{1P}+\alpha_{1G}+c(\beta_{1P}+\beta_{1G})+\gamma gI_0}{2(\beta_{1P}+\beta_{1G})}.$$

$\frac{\partial E\Pi}{\partial p_2} = \delta^2[\alpha_{2E}+\beta_{2E}(e_0I_0+e_1I_1+\varepsilon)+\alpha_{2P}-2\beta_{2P}p_2+\alpha_{2G}-2\beta_{2G}p_2+c(\beta_{2P}+\beta_{2G})+\gamma gI_1]=0$. This leads to

$$p_2 = \frac{\alpha_{2E}+\beta_{2E}(e_0I_0+e_1I_1+\varepsilon)+\alpha_{2P}+\alpha_{2G}+c(\beta_{2P}+\beta_{2G})+\gamma gI_1}{2(\beta_{2P}+\beta_{2G})}.$$

Inserting the assumed parameter values $c=0, \beta_{1E}=1=\beta_{1P}=\beta_{1G}$ and $\beta_{2E}=1=\beta_{2P}=\beta_{2G}$ and $e_0=1=e_1$, and $f=1=g$ into the above strategies we obtain that

investment at t = 0

$$I_0 = \frac{\delta[\theta p_{1u}(1+\gamma)+(1-\theta)p_{1d}(1+\gamma)]+\delta^2[p_2-\Delta d_1]}{1}$$

investment at t = 1

$$I_1 = \frac{\delta[p_2(1+\gamma)-\Delta d_1]}{1}$$

price at upstate

$$p_{1u} = \frac{\alpha_E + \alpha_P + \alpha_G + (I_0 + \varepsilon_u) + \gamma I_0}{4}.$$

price at downstate

$$p_{1d} = \frac{\alpha_E + \alpha_P + \alpha_G + (I_0 + \varepsilon_d) + \gamma I_0}{4}.$$

price at t = 2

$$p_2 = \frac{\alpha_E + \alpha_P + \alpha_G + (I_0 + I_1 + \varepsilon) + \gamma I_1}{4}.$$

Solving these first order conditions together will yield a unique optimal investment and price profile. Note that solving the optimization problem backward also yields the same solution.

Proof of Proposition 7

Without emotional consumers the following parameters will satisfy $\alpha_{1E} = 0 = \beta_{1E} = \alpha_{2E} = \beta_{2E}$ and $e_0 = 0 = e_1$ and $\theta = 1$.
The derivative of the expected discounted profit function of M with respect to time zero investment is
$\frac{\partial E\Pi}{\partial I_0} = - I_0 + \delta[p_1\gamma] + \delta^2[-\Delta d_1] = 0$. This leads to

$$I_0 = \delta[p_1\gamma] + \delta^2[-\Delta d_1]$$

The derivative of the expected discounted profit function of M with respect to time one investment is
$\frac{\partial E\Pi}{\partial I_1} = -\delta I_1 + \delta^2[(p_2\gamma) - \Delta d_1] = 0$, which results in

$$I_1 = \delta[p_2\gamma - \Delta d_1]$$

Similarly, the first order conditions with respect to prices are the following.
$\frac{\partial E\Pi}{\partial p_1} = \delta[(\alpha_P - 2p_1 + \alpha_G - 2p_1 + \gamma I_0)] = 0$. This leads to

$$p_1 = \frac{\alpha_P + \alpha_G + \gamma I_0}{4}.$$

$\frac{\partial E\Pi}{\partial p_2} = \delta^2[1 - 2\beta_{2P}p_2 + 1 - 2\beta_{2G}p_2 + \gamma I_1] = 0$. This leads to

$$p_2 = \frac{\alpha_P + \alpha_G + \gamma I_1}{4}.$$

Solving these strategies together yield the result in the proposition.

Proof of Corollary 1

This is a direct result by comparing Propositions 1 and 2. Using the unreduced form solution of the model in the proof of Proposition 1, observe that simultaneously the followings hold in limit:
$\lim_{\beta_{2E}\to 0} p_2^* > p_2^E$ and $\lim_{\beta_{2E}\to 0} I_1^* = I_1^E$. Furthermore, $\frac{\partial p_2^*}{\partial \beta_{2E}} > 0$ and $\frac{\partial I_1^*}{\partial \beta_{2E}} > 0$. Combining these result implies that $p_2^* > p_2^E$ and $I_1^* > I_1^E$.
Similarly, $\lim_{\beta_{1E}\to 0} p_{1u}^* = \lim_{\beta_{1E}\to 0} p_{1d}^* => p_1^E$ and $\lim_{\beta_{1E}\to 0} I_0^* = I_0^E$ when $\theta \to 1$ which corresponds to certainty case. Furthermore, $\frac{\partial p_{1u}^*}{\partial \beta_{1E}} > 0$ and $\frac{\partial p_{1d}^*}{\partial \beta_{1E}} > 0$ and $\frac{\partial I_0^*}{\partial \beta_{1E}} > 0$ and $\frac{\partial I_0^*}{\partial \beta_{2E}} > 0$.
For uncertainty case, let expected price at time 1 be $Ep_1^* = \theta p_{1u}^* + (1-\theta)p_{1d}^*$. Then similar limit arguments above apply. Combining these result consequently implies that $Ep_1^* > p_1^E$ and $I_0^* > I_0^E$.
The profit comparison is a direct result of prices because the aggregate demand curve that *M* faces will shift up by addition of emotional consumers. *M* charges monopoly price to all consumers whether emotional consumers are served or not. With addition of emotional consumers the total demand curve will increase and therefore the monopoly price charged to type 2 and type 3 consumers goes up when emotional consumers are also present. Therefore, *M*'s profit when all consumers are served will be higher than its profit when one type of consumer is excluded.

Proof of Proposition 8

Without green conscious consumers the following parameters will satisfy $\alpha_{1G} = 0 = \beta_{1G} = \alpha_{2G} = \beta_{2G}$ and $\gamma = 0$.
The derivative of the expected discounted profit function of *M* with respect to time zero investment is
$\frac{\partial E\Pi}{\partial I_0} = - I_0 + \delta[\theta p_{1u} + (1-\theta)p_{1d}] + \delta^2[p_2 - \Delta d_1] = 0$. This leads to

$$I_0 = \delta[\theta p_{1u} + (1-\theta)p_{1d}] + \delta^2[p_2 - \Delta d_1]$$

The derivative of the expected discounted profit function of M with respect to time one investment is
$\frac{\partial E\Pi}{\partial I_1} = -\delta I_1 + \delta^2[p_2 - \Delta d_1] = 0$, which results in

$$I_1 = \delta[p_2 - \Delta d_1]$$

Similarly, the first order conditions with respect to prices are the following.
$\frac{\partial E\Pi}{\partial p_{1u}} = \delta[\theta(\alpha_{1E} + (I_0 + \varepsilon_u) + \alpha_{1P} - 2p_{1u} - 2p_{1u})] = 0$. This leads to

$$p_{1u} = \frac{\alpha_{1E} + \alpha_{1P} + (I_0 + \varepsilon_u)}{4}.$$

$\frac{\partial E\Pi}{\partial p_{1d}} = \delta[(1-\theta)(\alpha_{1E} + (I_0 + \varepsilon_d) + \alpha_{1P} - 2p_{1d} - 2p_{1d})] = 0$. This leads to

$$p_{1d} = \frac{\alpha_{1E} + \alpha_{1P} + (I_0 + \varepsilon_d)}{4}.$$

$\frac{\partial E\Pi}{\partial p_2} = \delta^2[\alpha_{2E} + (I_0 + I_1 + \varepsilon) + \alpha_{2P} - 2p_2] = 0$. This leads to

$$p_2 = \frac{\alpha_{2E} + \alpha_{2P} + (I_0 + I_1 + \varepsilon)}{4}.$$

Solving these strategies yields the result in the proposition.

Proof of Proposition 9

Without price sensitive consumers the following parameters will satisfy $\alpha_{1P} = \alpha_{2P} = 0 = \beta_{1P} = \beta_{2P}$.
The derivative of the expected discounted profit function of *M* with respect to time zero investment is
$\frac{\partial E\Pi}{\partial I_0} = -I_0 + \delta[\theta p_{1u}(1+\gamma) + (1-\theta)p_{1d}(1+\gamma)] + \delta^2[p_2 - \Delta d_1] = 0$. This leads to

$$I_0 = \delta(1+\gamma)[\theta p_{1u} + (1-\theta)p_{1d}] + \delta^2[p_2 - \Delta d_1]$$

The derivative of the expected discounted profit function of M with respect to time one investment is
$\frac{\partial E\Pi}{\partial I_1} = -\delta I_1 + \delta^2[p_2(1+\gamma) - \Delta d_1] = 0$, which results in

$$I_1 = \delta[p_2(1+\gamma) - \Delta d_1]$$

Similarly, the first order conditions with respect to prices are the following.
$\frac{\partial E\Pi}{\partial p_{1u}} = \delta[\theta(\alpha_E + (I_0 + \varepsilon_u) + \alpha_G - 2p_{1u} + \gamma I_0)] = 0$. This leads to

$$p_{1u} = \frac{\alpha_E + \alpha_G + (1+\gamma)I_0 + \varepsilon_u}{2}.$$

$\frac{\partial E\Pi}{\partial p_{1d}} = \delta[(1-\theta)(\alpha_E + (I_0 + \varepsilon_d) + \alpha_G - 2p_{1d} + \gamma I_0)] = 0$. This leads to

$$p_{1d} = \frac{\alpha_E + \alpha_G + (1+\gamma)I_0 + \varepsilon_d}{2}.$$

$\frac{\partial E\Pi}{\partial p_2} = \delta^2[\alpha_E + (I_0 + I_1 + \varepsilon) + \alpha_G - 2p_2 + \gamma I_1] = 0$. This leads to

$$p_2 = \frac{\alpha_E + \alpha_G + I_0 + (1+\gamma)I_1 + \varepsilon}{2}.$$

Solving these strategies yields the result in the proposition.

Appendix B. Sensitivity analysis

	Parameter change	I_0	I_1	p_{1d}	p_{1u}	p_2	Profits
f	1.1	1.712698	1.322116	2.258698	2.383698	2.37827	6.316119
	1.2	1.515613	1.166263	2.185777	2.310777	2.295969	6.116943
	1.3	1.359253	1.043212	2.127923	2.252923	2.230895	5.959188
c	0.2	1.903922	1.474497	2.379451	2.504451	2.508554	6.180279
	0.3	1.83901	1.423137	2.405434	2.530434	2.531437	5.797964
	0.4	1.774098	1.371777	2.431416	2.556416	2.55432	5.428558
c_0	0.4	1.968833	1.525857	2.353468	2.478468	2.485671	6.530501
	0.5	1.968833	1.525857	2.353468	2.478468	2.485671	6.485501
	0.6	1.968833	1.525857	2.353468	2.478468	2.485671	6.440501
d_0	0.8	1.968833	1.525857	2.353468	2.478468	2.485671	6.603851
	0.9	1.968833	1.525857	2.353468	2.478468	2.485671	6.632201
	1	1.968833	1.525857	2.353468	2.478468	2.485671	6.688901
d_1	0.2	1.881382	1.432595	2.321112	2.446112	2.440233	6.325775
	0.3	1.793932	1.339333	2.288755	2.413755	2.394795	6.142996
	0.4	1.706481	1.246071	2.256398	2.381398	2.349357	5.970463
Δ	0.8	1.95634	1.512534	2.348846	2.473846	2.47918	6.547299
	0.9	1.943847	1.499211	2.344224	2.469224	2.472689	6.576005

(*continued on next column*)

(*continued*)

	Parameter change	I_0	I_1	p_{1d}	p_{1u}	p_2	Profits
	1	1.931354	1.485888	2.339601	2.464601	2.466198	6.604921
e_0	0.6	2.344074	1.619102	2.550909	2.675909	2.625679	6.966228
	0.7	2.800971	1.741558	2.801408	2.926408	2.809546	7.542272
	0.8	3.375448	1.904986	3.127074	3.252074	3.054935	8.299702
e_1	0.6	2.000407	1.716753	2.365151	2.490151	2.603168	6.679082
	0.7	2.037772	1.934517	2.378976	2.503976	2.742219	6.868995
	0.8	2.082388	2.186408	2.395483	2.520483	2.90825	7.095989
α_{1E}	1.1	2.015084	1.530967	2.420581	2.545581	2.493343	6.730258
	1.2	2.061335	1.536076	2.487694	2.612694	2.501015	6.947756
	1.3	2.107585	1.541185	2.554807	2.679807	2.508687	7.171293
α_{2E}	1.1	1.987495	1.572108	2.360373	2.485373	2.555117	6.714853
	1.2	2.006156	1.618358	2.367278	2.492278	2.624562	6.91653
	1.3	2.024817	1.664609	2.374182	2.499182	2.694007	7.123832
β_{2E}	0.6	2.180695	1.817649	2.431857	2.556857	2.745076	7.001018
	0.7	2.444762	2.181664	2.529562	2.654562	3.069132	7.602911
	0.8	2.783257	2.648612	2.654805	2.779805	3.485284	8.375329
β_{1E}	0.6	2.200419	1.551441	2.509166	2.659166	2.524086	6.863859
	0.7	2.468824	1.581092	2.691906	2.866906	2.568607	7.264133
	0.8	2.78366	1.615873	2.908729	3.108729	2.620831	7.733942
θ	0.6	1.980396	1.527134	2.357747	2.482747	2.487589	6.570958
	0.7	1.991959	1.528412	2.362025	2.487025	2.489507	6.623212
	0.8	2.003521	1.529689	2.366303	2.491303	2.491425	6.675562
α_{1P}	1.1	2.015084	1.530967	2.420581	2.545581	2.493343	6.730258
	1.2	2.061335	1.536076	2.487694	2.612694	2.501015	6.947756
	1.3	2.107585	1.541185	2.554807	2.679807	2.508687	7.171293
α_{2P}	1.1	1.987495	1.572108	2.360373	2.485373	2.555117	6.714853
	1.2	2.006156	1.618358	2.367278	2.492278	2.624562	6.91653
	1.3	2.024817	1.664609	2.374182	2.499182	2.694007	7.123832
β_{2P}	0.6	1.889014	1.328031	2.323935	2.448935	2.188635	6.097074
	0.7	1.826548	1.173211	2.300823	2.425823	1.956172	5.767071
	0.8	1.776329	1.048748	2.282242	2.407242	1.769291	5.501815
β_{1P}	0.6	1.775878	1.504541	2.079159	2.192795	2.453665	6.074524
	0.7	1.623759	1.487736	1.863159	1.967326	2.428432	5.724306
	0.8	1.500753	1.474147	1.688676	1.78483	2.408029	5.441148
α_{1G}	1.1	2.015084	1.530967	2.420581	2.545581	2.493343	6.730258
	1.2	2.061335	1.536076	2.487694	2.612694	2.501015	6.947756
	1.3	2.107585	1.541185	2.554807	2.679807	2.508687	7.171293
α_{2G}	1.1	1.987495	1.572108	2.360373	2.485373	2.555117	6.714853
	1.2	2.006156	1.618358	2.367278	2.492278	2.624562	6.91653
	1.3	2.024817	1.664609	2.374182	2.499182	2.694007	7.123832
β_{2G}	0.6	1.889014	1.328031	2.323935	2.448935	2.188635	6.097074
	0.7	1.826548	1.173211	2.300823	2.425823	1.956172	5.767071
	0.8	1.776329	1.048748	2.282242	2.407242	1.769291	5.501815
β_{1G}	0.6	1.775878	1.504541	2.079159	2.192795	2.453665	6.074524
	0.7	1.623759	1.487736	1.863159	1.967326	2.428432	5.724306
	0.8	1.500753	1.474147	1.688676	1.78483	2.408029	5.441148
g	0.8	2.311182	1.838627	2.561029	2.686029	2.708542	7.081107
	0.9	2.744572	2.234947	2.832611	2.957611	3.001448	7.819284
	1	3.315094	2.758031	3.19967	3.32467	3.399451	8.820468
γ	0.8	2.311182	1.838627	2.561029	2.686029	2.708542	7.081107
	0.9	2.744572	2.234947	2.832611	2.957611	3.001448	7.819284
	1	3.315094	2.758031	3.19967	3.32467	3.399451	8.820468
δ	0.95	2.173956	1.66479	2.429364	2.554364	2.562717	7.290007
	0.98	2.305826	1.75298	2.478156	2.603156	2.611831	7.787512
	1	2.397712	1.813947	2.512154	2.637154	2.645874	8.134763

References

Albers-Miller, N.D., Stafford, M.R., 1999. An international analysis of emotional and rational appeals in services vs goods advertising. J. Consum. Market. 16 (1), 42–57.

Conlisk, J., 1996. Why bounded rationality. J. Econ. Lit. 34 (2), 669–700.

Damasio, A., 1999. The Feelings of what Happens: Body and Emotion in Making of Consciousness, first ed. Harcourt Brace, New York.

De Giovanni, P., 2014. Environmental collaboration in a closed-loop supply chain with a reverse revenue sharing contract. Ann. Oper. Res. 220 (1), 135–157.

De Giovanni, P., Ramani, V., 2017. Product cannibalization and the effect of a service strategy. J. Oper. Res. Soc. 1–17.

De Giovanni, P., Zaccour, G., 2019a. A selective survey of game-theoretic models of closed-loop supply chains. 4OR 1–44.

De Giovanni, P., Zaccour, G., 2019b. Optimal quality improvements and pricing strategies with active and passive product returns. Omega 88, 248–262.

Dufwenberg, M., 2002. Marital investments, time consistency and emotions. J. Econ. Behav. Organ. 48, 57–69.

Elster, J., 1998. Emotions and economic theory. J. Econ. Lit. 36, 47–74.

Frijda, N., 2000. Emotions. In: Pawlik, K., Rosenzweig, M. (Eds.), International Handbook of Psychology. Sage, London, pp. 207–222.
Funk, S., Gilad, E., Watkins, C., Jansen, V.A., 2009a. The spread of awareness and its impact on epidemic outbreaks. Proc. Natl. Acad. Sci. U.S.A. 106 (16), 6872–6877.
Funk, C., Putnam, M., Gazzaniga, M., 2009b. Consciousness. In: Bernston, G., Cacioppo, J. (Eds.), Handbook of Neuroscience for the Behavioral Science. J.Wiley, Inc, pp. 482–503 ch. 25.
Garcia, A., Shen, J., 2010. Equilibrium capacity expansion under stochastic demand growth. Oper. Res. 58 (1), 240–255.
Geanakoplos, J., Pearce, D., Stacchetti, E., 1989. Psychological games and sequential rationality. Game. Econ. Behav. 1, 60–79.
Genc, T.S., 2017. The impact of lead time on capital investments. J. Econ. Dynam. Contr. 82, 142–164.
Genc, T.S., De Giovanni, P., 2017. Trade-in and save: a two-period closed-loop supply chain game with price and technology dependent returns. Int. J. Prod. Econ. 183, 514–527.
Genc, T.S., De Giovanni, P., 2018. Optimal return and rebate mechanism in a closed-loop supply chain game. Eur. J. Oper. Res. 269, 661–681.
Genc, T.S., Zaccour, G., 2013. Capacity investments in a stochastic dynamic game: equilibrium characterization. Oper. Res. Lett. 41 (5), 482–485.
Guide Jr., V.D.R., Li, J., 2010. The potential for cannibalization of new products sales by remanufactured products. Decis. Sci. J. 41 (3), 547–572.
Joshi, Y., Rahman, Z., 2015. Factors affecting green purchase behaviour and future research directions. Int. Rev. Strat. Manag. 3 (1–2), 128–143.
Kim, C., Jeon, H.G., Lee, K.C., 2020. Discovering the role of emotional and rational appeals and hidden heterogeneity of consumers in advertising copies for sustainable marketing. Sustainability 12 (12), 5189.
Liu, B., De Giovanni, P., 2019. Green process innovation through Industry 4.0 technologies and supply chain coordination. Ann. Oper. Res. 1–36.
Loewenstein, G., 2000. Emotions in economic theory and economic behavior. Am. Econ. Rev. 90 (2), 426–432.
Loomes, G., Sugden, R., 1982. Regret theory: an alternative theory of rational choice under uncertainty. Econ. J. 92, 805–824.
Mattsson, Lars-Göran, Weibull, Jörgen W., 2002. Probabilistic choice and procedurally bounded rationality. Game. Econ. Behav. 41, 61–78.
Murad, M., Resende, P.V., Cezarino, L.O., FalcoSales, W., 2020. Being green makes me greener? An evaluation of sustainability rebound effects. J. Clean. Prod. 121436.
Preeker, T., De Giovanni, P., 2018. Coordinating innovation projects with high tech suppliers through contracts. Research Pol. 47 (6), 1161–1172.
Ramani, V., De Giovanni, P., 2017. A two-period model of product cannibalization in an atypical Closed-loop Supply Chain with endogenous returns: The case of DellReconnect. Eur. J. Oper. Res. 262 (3), 1009–1027.
Saunila, M., Ukko, J., Rantala, T., 2018. Sustainability as a driver of green innovation investment and exploitation. J. Clean. Prod. 179, 631–641.
Sdrolia, E., Zarotiadis, G., 2019. A comprehensive review for green product term: from definition to evaluation. J. Econ. Surv. 33 (1), 150–178.
Tulving, E., 2002. Episodic memory: from mind to brain. Annu. Rev. Psychol. 53, 1–25.
Yang, D., Xiao, T., Huang, J., 2019. Dual-channel structure choice of an environmental responsibility supply chain with green investment. J. Clean. Prod. 210, 134–145.
Zhang, X., Yousaf, H.A.U., 2020. Green supply chain coordination considering government intervention, green investment, and customer green preferences in the petroleum industry. J. Clean. Prod. 246, 118984.