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The Matrix: How Society Forces Us to be Eco-friendly

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An abstract of
a thesis submitted to the Faculty of Emory College of Arts and Sciences
of Emory University in partial fulfillment
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Abstract

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In this paper, we construct a theoretical model of environmental behavior based on the assumption that an individual's decisions are motivated by the behavior of those around him. We examine the conditions under which an indiviudual chooses to be green and determine the choices he or she must make in order for both individual and society to derive maximum benefit. Within the bounds of our model, three Nash equilibria exist: either everyone is eco-friendly, everyone is eco-unfriendly, or the world is split into polluters and eco-warriors. Every individual is best off when the entire world chooses to be eco-friendly. However, under certain conditions, unanimous environmental irresponsibility is a preferable outcome to a world divided in choice. This result has implications that can be extended to the real world. We define an individual's "tipping-point" to be the smallest expected number of eco-friendly individuals required to convince him or her to be eco-friendly. By instituting policies that either decrease this tipping-point or inflate the perceived number of eco-friendly individuals, government agencies can push society towards universal environmental responsibility.

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I. Introduction:

The last few years have seen a rise in socially responsible behavior (The National Geographic Society & GlobeScan, 2008, 2009, 2010) amongst, not only individuals, but corporate entities and social groups. One important manifestation of this global phenomenon is the push to become eco-friendly. More and more people are cleaning up parks, taking public transportation, recycling, eating organically and minimizing their water usage. Companies are modifying the way they do business in order to ensure that they become carbon-neutral.

Why is it that attitudes have changed so much over the few decades? One possible explanation is that scientists are constantly gathering pieces of evidence that point to new and more alarming consequences of global warming, which are then escalated in the media. A more plausible explanation for this shift in attitudes would be that there is an unspoken pressure that society places on an individual to demonstrate environmental responsibility. The fraction of society that is eco-friendly constitutes a moral force that grows in strength as its numbers increase. We claim that censure from these eco-warriors, whether explicit or implicit, is a driver of eco-friendly behavior. After all, who wants to be the only person in the neighborhood without a recycling bin outside their house? In this paper, we build a theoretical model of eco-friendly behavior and examine the conditions under which an individual chooses to be green. We also determine the choices each individual must make in order for both individual and society to derive maximum benefit.

Within the bounds of our model, three Nash equilibria exist: either everyone is eco-friendly, everyone is eco-unfriendly, or the world is split into polluters and eco-warriors. It comes as no surprise that every individual is best off when the entire world chooses to be eco-friendly. However, we also find that unanimous environmental irresponsibility is a preferable outcome to a society divided in choice. This result has implications that can be extended to the real world. The choice to be eco-friendly is largely motivated by how many other people one expects to be environmentally responsible. We define an individual's "tipping-point" to be the smallest expected number of eco-friendly individuals required to convince him or her to be eco-friendly. By instituting policies that either decrease this tipping-point, or inflate the perceived number of eco-friendly individuals, government agencies can push society towards universal environmental responsibility.

II. Background:

This paper is based in part on a game theoretic model presented by Kaushik Basu in his paper, "One Kind of Power" (1986). His model attempts to explain the existence of self-perpetuating dictatorships. In a totalitarian regime, the dictator has the power to enforce punishments in order to maintain his subjects' loyalty. Even though every individual will be better off if they collectively choose to be disloyal and overthrow the dictator, no single person makes this decision. Every individual will remain loyal and the regime is thus sustained. One can apply this model to explain what the Czech poet Vaclav Havel calls a "post-totalitarian system" (1978), which differs from a classical dictatorship in that the dictator is faceless. Havel uses the example of a green grocer who places a sign with the slogan "Workers of the World, Unite!" in his shop window. He does this not because he believes in the message on display, nor because he will be punished for failing to display it. He puts the sign in his window simply because it is the way things have always been done. He fears that if he breaks the status quo, he will be forced to face societal retribution. Therefore, even though each individual in this system would be better off if they collectively chose to rebel against meaningless social norms, they individually choose to conform and perpetuate a culture of social repression. In this paper, we construct a model in which eco-friendly behavior is similarly motivated by expectations about others' choices, and fear of societal disapproval.

As will be demonstrated later on, our model also incorporates elements of the particular species of "externality" described in Schelling's "Hockey Helmets, Concealed Weapons and Daylight Savings" (1973). In his paper, Schelling elaborates various situations in which players are faced with two alternatives. Their decision depends on the supposition that other players will behave in a certain way. Every player's choice affects either or both the choices and/or payoffs of the other players in the game, thus creating an externality. We construct a model in which individuals are similarly faced with a binary choice: whether or not to be eco-friendly. Each player's choice influences both the behavior and utility of other individuals in the game. Like Schelling, we are not concerned with the amount of reparative or preventative work they do for the environment. Rather, we would like to know whether or not they choose to do such work and how many of them make this decision.

III. The General Model:

In this section we present our model of environmentally conscious behavior. We begin with our assumptions.

(i) There are P people in the world, and each person can choose to either engage in eco-friendly practices, or to behave in an environmentally irresponsible manner. It is important to note that, in this framework, an individual's choice set consists of two possible decisions: eco-friendly behavior or eco-unfriendly behavior. We disregard the existence of degrees of these behaviors. In other words, we normalize the act, of say, recycling, to either action or inaction; either an individual recycles or he doesn't.

(ii) Eco-friendly individuals help the environment. Every individual begins with an endowment of w from which, if he or she chooses to be eco-friendly, is subtracted a quantity e. This e adds to the health of the environment, which we consider to be a public good.

(iii) Individuals who are not eco-friendly hurt the environment. They each detract a quantity n from the health of the environment.

(iv) There is strength in numbers. Every individual derives positive utility from every other person who makes the same choice that he or she does. If E people choose to be eco-friendly and $(w - e) = x$, then each eco-friendly individual receives a psychological benefit of Ex from the support of others like him or her. Similarly, if N people choose not to be eco-friendly, each of these individuals receives a psychological benefit of Nw units. Although, typically, Nw and Ee would be scaled down by some factor between one and zero, we make the simplifying assumption that it is not.

(v) There are two types of people in world; those who inherently care (C-type people) and those who don't care (D-type people) about the environment.

There are C C-type people and D D-type people in the population, such that $C + D = P$. Cs incur a cost of c, while Ds incur a cost of d from being eco-friendly. The Cs, receive a "warm glow" from performing a service that they think will save the environment. Ds do not receive this "warm glow". Therefore, $c < d$.

(vi) Eco-friendly individuals frown on environmentally irresponsible behavior. If an individual chooses not to be eco-friendly, he or she incurs societal disapproval equal to k from each individual who chooses to be eco-friendly. In other words, if E individuals are eco-friendly, each individual who chooses not to be eco-friendly endures Ek units of societal censure.

(vii) Cs and Ds are influenced to a different extent by societal disapproval. We call this susceptibility to disapproval their disapproval preference parameter. Cs and Ds have disapproval preference parameters of a and b, where $a > b$, and $a,b \in [0,1]$. Thus, a C endures a net societal disapproval of Eka, while a D receives a net disutility of Ekb from choosing not to be eco-friendly.

(viii) Every individual knows his or her type, and what proportion of the population are Cs and Ds. So, although he or she cannot be sure of how many people will choose to be eco-friendly, he or she can use this knowledge to make a good estimation of the same.

(ix) It is only reasonable that an individual is not penalized by an amount greater than his or her initial endowment. Therefore, $n,k,c,d < w$.

III.1 Utility Functions:

From the above assumptions, we can derive a C-type individual's utility function. If he or she is eco-friendly, he or she will receive a utility of U_E^C where

$$U_E^C = Ex + Ee - Nn - c. \tag{3.1}$$

Here, *Ex* is the utility this individual derives from other people who choose to be eco-friendly. *Ee* is the amount that eco-friendly individuals contribute to the public good, while *Nn* is the harm that eco-unfriendly individuals inflict on it.

If a C-type individual chooses not to be eco-friendly, he or she will receive a utility

$$U_N^C = Nw + Ee - Nn - Eka, \tag{3.2}$$

where *Nw* is the utility an eco-unfriendly individual receives from the support of others like him or her. *Ee – Nn* is the net amount of the public good, and *Eka* is the net disutility a C incurs from the disapproval of eco-friendly individuals.

If a D-type individual chooses to be eco-friendly, he or she will receive a utility of

$$U_E^D = Ex + Ee - Nn - d, \tag{3.3}$$

which is identical to (3.1) save for the increased cost of eco-friendly behavior, *d.* If he or she chooses not to be eco-friendly, he or she will earn a utility of

$$U_N^D = Nw + Ee - Nn - Ekb, \tag{3.4}$$

which is identical to (3.2) except for the decreased net cost from disapproval, *Ekb.*

Setting equations (3.1) and (3.2) equal to each other, we find that a C is indifferent between being eco-friendly and not being eco-friendly when the number of people her or she expects to behave in an environmentally responsible manner is

$$E_C = \frac{Pw + c}{w + x + ka}. \tag{3.5}$$

If E is greater than this amount, a C will be eco-friendly, and if it is less than this quantity, he or she will choose not to be eco-friendly. We call E_C the "tipping point" for C-type individuals.

Similarly, we find the' "tipping-point" for Ds to be

$$E_D = \frac{Pw + d}{w + x + kb}. \tag{3.6}$$

Since $c < d$ and $a > b$,

$$E_C < E_D. \tag{3.7}$$

Furthermore, it will be later shown that $0 < E_C$ and $E_D < P$. The first inequality implies that if the expected number of eco-friendly people is sufficiently small, even C-type people will choose to be eco-unfriendly. The second inequality implies that if the expected number of eco-friendly people is large enough, even D-type individuals will choose to be eco-friendly.

From (3.7), we can identify the following best responses as summarized in proposition 1.

Proposition 1:

(a) *If $E < E_C$, both C and D-type individual prefer not to be eco-friendly.*

(b) *If $E_C < E < E_D$, C-type people prefer to be eco-friendly and D-type people prefer not to be eco-friendly.*

(c) *If $E > E_D$, both C and D-type individuals prefer to be eco-friendly.*

Proof:

To show **(a)**, note that

Since $E < E_C \Rightarrow U_E^C < U_N^C$. Therefore Cs will not be eco-friendly.

Using (3.7), $E_C < E_D \Rightarrow E < E_C < E_D \Rightarrow U_E^D < U_N^D$. Therefore Ds will not be eco-friendly.

To show **(b)**, note that

Since $E > E_C \Rightarrow U_E^C > U_N^C$. This implies that Cs will choose to be eco-friendly

Since $E < E_D \Rightarrow U_E^C < U_N^C$. This implies that Ds will choose not to be eco-friendly.

To show **(c)**, note that

Since $E > E_D \Rightarrow U_E^D > U_N^D$. Therefore Ds will choose to be eco-friendly.

Using (3.7), $E_D > E_C \Rightarrow E > E_D > E_C \Rightarrow U_E^C > U_N^C$. Cs will be environmentally responsible. ■

Fig 3.1.1 and 3.1.2 graphically demonstrate these best responses. In both graphs, The x-axis measures the expected number of environmentally friendly individuals in the world, *E*. The green line depicts the utility an individual derives from being eco-friendly, while the red line demarcates the utility he or she obtains from environmental irresponsibility. At $E = E_C$ and $E = E_D$, the red and green lines in fig. 3.1.1 and 3.1.2 intersect. If *E* is less than E_C, the red lines lie above the green lines in both fig 3.1.1 and 3.1.2. Therefore, both Cs and Ds will choose to be eco-unfriendly in order to maximize their utility. Similarly, when *E* is greater than E_D, the green line rests above the red line in fig. 3.1.1 and fig 3.1.2. Thus, Cs and Ds will both choose to be eco-friendly. When *E* lies between E_C and E_D, the green line lies above the red line in fig. 3.1.1. However, in fig. 3.1.2, the opposite is true. Therefore, Cs will choose to be eco-friendly, while Ds will not.

Fig. 3.1.1. Utility of C-type Individual

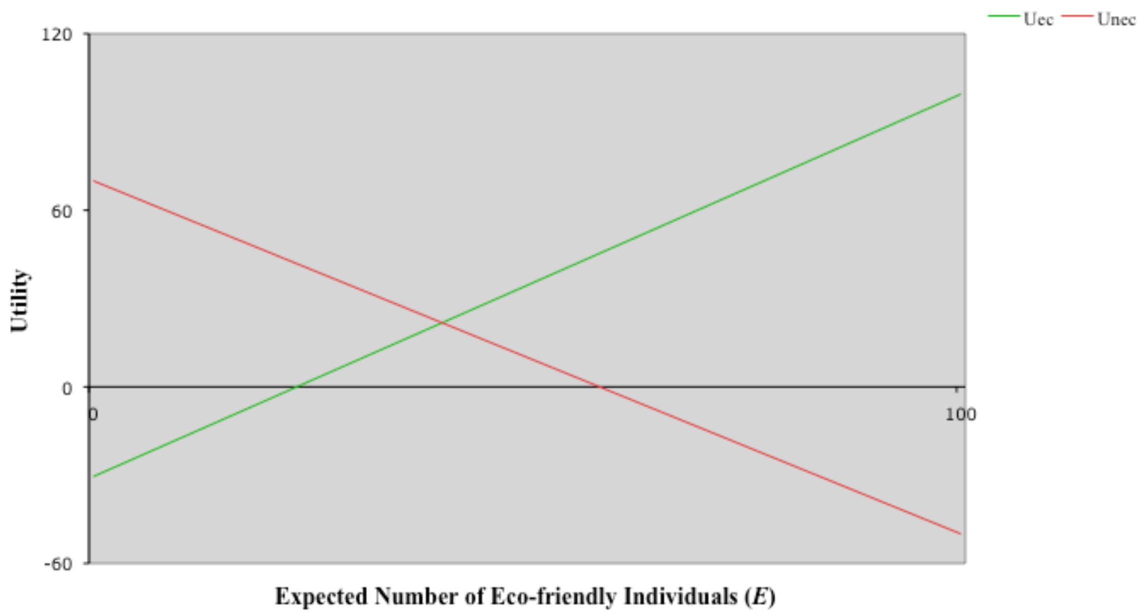


Fig. 3.1.2. Utility of D-type Individuals

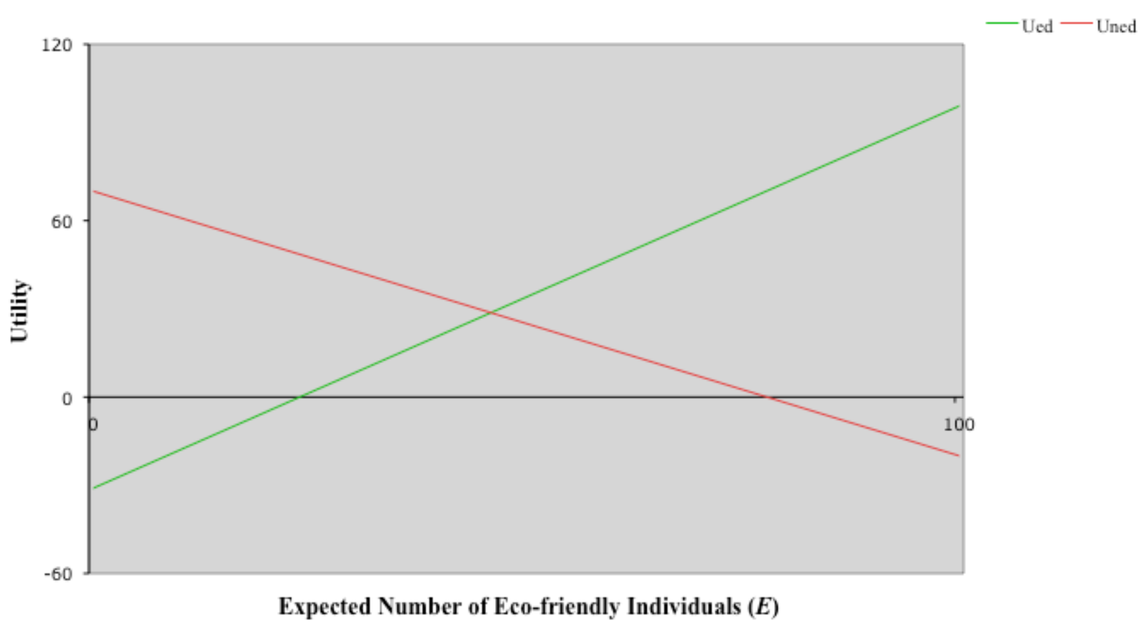


Table 2. Values used in fig. 3.1.1, 3.1.2 and 3.1.3.

E	***N***	***w***	***e***	***x***	***n***	***c***	***d***	***k***	***a***	***b***
0 - 100	100 - 0	1	0.2	0.8	0.3	0.5	1	1	0.7	0.4

From Proposition 1, we arrive at the following three Nash equilibria as enumerated in proposition 2.

Proposition 2:

(a) *There always exists an equilibrium in which everyone is eco-unfriendly (Equilibrium 1).*

(b) *There always exists an equilibrium in which everyone is eco-friendly (Equilibrium 2).*

(c) *If* $E_C < C < E_D$*, there also exists an equilibrium in which only C-type individuals are eco-friendly while only D-type individuals are eco-unfriendly (Equilibrium 3).*

Proof:

To show **(a)**, note that

from proposition 1(a), when $E < E_C$, everyone chooses not to be eco-friendly. Thus, there exists an equilibrium where everyone is not eco-friendly. We must now show that $0 < E_C < P$. Clearly,

$$Pw + c > 0,$$

and

$$w + x + ka > 0,$$

$$\Rightarrow \frac{Pw + c}{w + x + ka} > 0. \tag{3.8}$$

We know,

$$\frac{Pw}{w+x+ka} < P. \tag{3.9}$$

Also, from assumption (ix),

$$c < w < w + x + ka$$

$$\Rightarrow \frac{c}{w+x+ka} < 1. \tag{3.10}$$

From (3.8), (3.9) and (3.10),

$$0 < E_D < P. \tag{3.11}$$

This implies that when $E = 0 < E_C$, using proposition 1(a), every individual's best response is to be eco-unfriendly. Thus it is a Nash equilibrium for everyone to be eco-unfriendly.

To show **(b)**, note that

from proposition 1(c), when $E > E_D$, everyone chooses to be eco-friendly. Thus, there exists an equilibrium where everyone is eco-friendly. We must now show that $0 < E_D < P$. Clearly,

$$Pw + d > 0,$$

and

$$w + x + kb > 0,$$

$$\Rightarrow \frac{Pw+d}{w+x+kb} > 0. \tag{3.12}$$

We know,

$$\frac{Pw}{w+x+kb} < P. \tag{3.13}$$

Also, from assumption (ix),

$$d < w < w + x + kb$$
$$\Rightarrow \frac{d}{w+x+kb} < 1. \tag{3.14}$$

From (3.8), (3.9) and (3.10),

$$0 < E_D < P. \tag{3.15}$$

This implies that when $E = P > E_D$, using proposition 1(a), every individual's best response is to be eco-friendly. Thus it is a Nash equilibrium for everyone to be eco-friendly.

To show **(c)**, note that

from (3.7),

$$E_C < E_D.$$

Therefore, using (3.11) and (3.15),

$$0 < E_C < E_D < P. \tag{3.16}$$

Suppose $E = C \in (E_C, E_D)$, where C is the total number of C-type people. Then, from proposition 1(b), Cs will choose to be eco-friendly, while Ds will choose not to be eco-friendly. Thus, when $E_C < C < E_D$, it is a Nash equilibrium for Cs to be eco-friendly and Ds to be eco-unfriendly. ■

III.2 Comparative Statics

From (3.5) and (3.6), we arrive at the following conclusions:

1. $\frac{\partial E_C}{\partial c} > 0$ and $\frac{\partial E_D}{\partial d} > 0$. Holding all other exogenous variables constant, if the cost of engaging in eco-friendly behavior increases, then individuals would require a higher expected number of eco-friendly people to convince them to be eco-friendly as well. The additional strength in numbers would compensate for the increased costs of eco-friendly behavior.

2. $\frac{\partial E_C}{\partial c} < \frac{\partial E_D}{\partial d}$. Cs have greater eco-friendly tendencies than Ds because they inherently value the environment more than Ds do. Therefore, an increase in their marginal cost of eco-friendly behavior, *c*, affects their choice to a lesser extent than an equal increase in *d* affects Ds' behavior.

3. $\frac{\partial E_C}{\partial k} < 0$ and $\frac{\partial E_D}{\partial k} < 0$. We can interpret this to mean that if societal disapproval of environmentally irresponsible behavior increases, individuals require a smaller expected number of eco-friendly individuals to convince them to behave in an eco-friendly manner. Recycling becomes a much more attractive option if eco-warriors start protesting outside your doorstep every time you throw your beer cans in the dumpster.

4. The relationship between $\left|\frac{\partial E_C}{\partial k}\right|$ and $\left|\frac{\partial E_D}{\partial k}\right|$ is not readily apparent. We would expect Cs' behavior to be affected to a greater extent by societal disapproval than Ds' behavior. However, we cannot make a generalization in this case.

5. $\frac{\partial E_C}{\partial w} > 0$ and $\frac{\partial E_D}{\partial w} > 0$. It comes as no surprise that as an individual's initial endowment increases, it takes a greater expected number of eco-friendly

individuals to convince him or her to forgo the multiplicative benefits of his entire endowment for the multiplicative benefits of a reduced amount *x*.

6. $\frac{\partial E_C}{\partial w} < \frac{\partial E_D}{\partial w}$. This result is hardly astonishing. After all, Cs care more deeply about the health of the environment that Ds. They also derive greater disutility from societal disapproval when eco-unfriendly. Therefore, an increase in initial endowment, holding *x* constant, influences a C-type person to a smaller extent than it does a D-type person.

7. $\frac{\partial E_C}{\partial x} < 0$ and $\frac{\partial E_D}{\partial x} < 0$. This result is intuitive: if being eco-friendly requires a smaller contribution towards the environment, it would take a smaller expected *E* to convince an individual to be eco-friendly.

8. $\left|\frac{\partial E_C}{\partial x}\right| < \left|\frac{\partial E_D}{\partial x}\right|$. Since C individuals' inherent value of the environment is greater than that of Ds, allowing them to keep more of their initial endowment has a smaller absolute effect on their behavior than an equal increase in *x* has on a D's behavior.

9. $\frac{\partial E_C}{\partial a} < 0$ and $\frac{\partial E_D}{\partial b} < 0$. This implies that as each individual's sensitivity to societal disapproval increases, it takes a smaller expected number of eco-friendly people to convince him or her to be eco-friendly.

10. $\left|\frac{\partial E_C}{\partial a}\right| < \left|\frac{\partial E_D}{\partial b}\right|$. This implies that an increase in C's sensitivity to societal disapproval affects C's behavior to a smaller extent than an equal increase in D's disapproval preference parameter influences D's behavior. This is surprising, given that Cs care more about societal disapproval than Ds.

III.3 Social Welfare

Using (3.1), (3.2), (3.3) and (3.4), we examine the individual and social efficiency of the three Nash equilibria found in section III.2.

Eq.1. C and D-type individuals choose not to be eco-friendly.

Each C's utility will be

$$U_{E1}^{C} = P(w-n), \tag{3.17}$$

while each D's utility will be

$$U_{E1}^{D} = P(w-n). \tag{3.18}$$

Therefore the welfare of the entire population amounts to

$$W_1 = C\big[P(w-n)\big] + D\big[P(w-n)\big] = P^2(w-n), \tag{3.19}$$

where $C + D = P$.

Eq.2. C and D-type individuals choose to be eco-friendly.

Each C's utility will be

$$U_{E2}^{C} = Px + Pe - c = Pw - c, \tag{3.20}$$

while each D's utility will be

$$U_{E2}^{D} = Px + Pe - d = Pw - d. \tag{3.21}$$

The societal welfare in this case would be

$$W_2 = C(Pw-c) + D(Pw-d)$$

$$W_2 = P^2 w - Cc - Dd. \tag{3.22}$$

Eq.3 $E = C \in (0,1)$.Cs choose to be eco-friendly and Ds choose not to be eco-friendly.

Each C's utility will be

$$U_{E3}^{C} = Cx + Ce - Dn - c = Cw - Dn - c, \tag{3.23}$$

while each D's utility will be

$$U_{E3}^{D} = Dw + Ce - Dn - Ckb = D(w-n) + Ce - Ckb. \tag{3.24}$$

Thus, the entire population derives a utility of

$$W_3 = C\big[Cw - Dn - c\big] + D\big[D(w-n) + Ce - Ckb\big]$$

$$W_3 = (C^2 + D^2)w + CD(e - n - kb) - D^2 n - Cc. \tag{3.25}$$

We are characterizing a global phenomenon. Thus we will consider the asymptotic case, where $P \longrightarrow \infty$.

Claim 1: In large populations, Cs are best off when everyone is eco-friendly.

Proof:

From (3.17), (3.20) and (3.23), as $P \to \infty$, $U_{E2}^{C} > U_{E1}^{C}$ and $U_{E2}^{C} > U_{E3}^{C}$. The relationship between U_{E3}^{C} and U_{E1}^{C} depends on the values of *C, D, n, w* and *c.* However, it is obvious that C's individual utility is maximized when everyone is eco-friendly. Further, fig. 3.1.1 demonstrates that a C's utility from being eco-friendly at $E = P$ is greater than his or her utility from either choice at any other *E*. ■

Claim 2: In large populations, Ds are best off when everyone is eco-friendly.

Proof:

From (3.18), (3.21) and (3.24), as $P \to \infty$, $U_{E2}^{D} > U_{E1}^{D}$ and $U_{E2}^{D} > U_{E3}^{D}$. The relationship between U_{E3}^{D} and U_{E1}^{D} depends on the values of *C, D, e, k* and *b.* Regardless, it is clear that

D's individual utility is maximized when the entire population, including himself or herself, chooses to be eco-friendly. Fig. 3.1.2 demonstrates that a D's utility from being eco-friendly at $E = P$ is greater than his or her utility at any other E. ■

We have thus established that, on an individual level, it is optimal for the entire population to behave in an environmentally responsible manner. We will now consider the welfare of the entire population in aggregate.

Claim 3: In large populations, the world is best off when every individual in it is eco-friendly.

Proof:

As $P \to \infty$,

$$P^2 n > Cc + Dd$$

$$\Rightarrow P^2(w - n) < P^2 w - Cc - Dd \tag{3.26}$$

From (3.19) and (3.22),

$$W_1 < W_2. \tag{3.27}$$

Also, as $P \to \infty$,

$$2CDw > CDe$$

where $C + D = P$ and $e < w$. This implies,

$$\begin{gathered} C^2 w + D^2 w + 2CDw > C^2 w + D^2 w + CDe \\ \Rightarrow P^2 w > (C^2 + D^2)w + CDe \end{gathered} \tag{3.28}$$

Also,

$$CD(n + kb) + D^2 n + Cc > Cc + Dd \tag{3.29}$$

where $C + D = P$ and $n,k,c,d \in [0,w]$. From (3.22), (3.25), (3.28) and (3.29),

$$P^2 w - Cc - Dd > (C^2 + D^2)w - CD(n + kb) - D^2 n$$

$$\Rightarrow W_3 < W_2 \blacksquare$$

We have thus demonstrated that it is optimal for society as a whole if the entire population chooses to behave in an eco-friendly fashion.

IV. The Continuous Model

In the previous section, we examined eco-friendly behavior in a game with *P* players of two types – C and D. In this section, we will generalize our results to a game of *P* players of infinitely many species. This requires that we modify assumption (v) from the previous model as follows:

(v) Each individual *i,* is influenced to a different extent by societal displeasure. We call this susceptibility to disapproval his or her disapproval preference parameter, θ_i, where $\theta_i \in [0,1]$ and θ_i is uniformly distributed over [0,1]. Thus, each eco-unfriendly *i* receives a total disutility of Ek units and a net disutility of $Ek\theta_i$ units from the disapproval of *E* eco-friendly individuals. Further, individuals who behave in an environmentally responsible manner receive a “warm glow” from the knowledge that they have performed a charitable act. This warm glow is inversely proportional to their preference parameter. In other words, the more they care about public opinion, the smaller the cost they incur from being eco-friendly. Thus, if each individual incurs an absolute cost of *h* units from being eco-friendly, he or she incurs a net cost of $(1 - \theta_i)h$ from the same.

IV.1 Utility Functions

From our assumptions, we can derive each *i*'s utility function. If *i* chooses to be eco-friendly, he or she will receive a utility of U_E^i where

$$U_E^i = Ex + Ee - Nn - (1-\theta_i)h, \tag{4.1}$$

and if he or she chooses not to be eco-friendly, he or she will earn a utility of U_N^i equal to

$$U_N^i = Nw + Ee - Nn - Ek\theta_i. \tag{4.2}$$

Let the marginal individual in this universe have a preference parameter of $\overline{\theta}$. The marginal individual is that person who is indifferent between being eco-friendly and being environmentally irresponsible. We will later demonstrate that $P\overline{\theta}$ individuals choose to be eco-unfriendly and $P(1-\overline{\theta})$ individuals choose to be eco-friendly. Therefore, the utility the marginal individual derives from being eco-friendly is

$$\overline{U}_E = P(1-\overline{\theta})x + P(1-\overline{\theta})e - P\overline{\theta}n - (1-\overline{\theta})h \tag{4.3}$$

and his or her utility from choosing not to be eco-friendly is

$$\overline{U}_N = P\overline{\theta}w + P(1-\overline{\theta})e - P\overline{\theta}n - P(1-\overline{\theta})k\overline{\theta}. \tag{4.4}$$

Setting (4.3) and (4.4) equal to each other, we arrive at the following relationship for the marginal individual:

$$Pk\overline{\theta}^2 + \overline{\theta}(Pw + Px - Pk - h) + h - Px = 0. \tag{4.5}$$

We thus identify three categories of people.

1. $\theta_i = \overline{\theta}$. This individual is indifferent between being and not being eco-friendly.
2. $\theta_i < \overline{\theta}$. All such *i*s choose not to be eco-friendly.

   Proof:

   Since

$$\theta_i < \bar{\theta} \Rightarrow (1-\theta_i) > (1-\bar{\theta}),$$

using (4.1) and (4.3),

$$U_E^i < \bar{U}_E \tag{4.6}$$

Also, since

$$\theta_i < \bar{\theta} \Rightarrow (1-\bar{\theta})k\theta_i < (1-\bar{\theta})k\bar{\theta},$$

using (4.2) and (4.4),

$$\bar{U}_N < U_N^i \tag{4.7}$$

Thus, from (4.6) and (4.7),

$$U_E^i < \bar{U}_E = \bar{U}_N < U_N^i \;\blacksquare \tag{4.8}$$

3. $\theta_i > \bar{\theta}$. All such individuals choose to be eco-friendly.

Proof:

Since,

$$\theta_i > \bar{\theta} \Rightarrow (1-\theta_i) < (1-\bar{\theta}),$$

using (4.1) and (4.3),

$$U_E^i > \bar{U}_E. \tag{4.9}$$

Also, since

$$\theta_i > \bar{\theta} \Rightarrow (1-\bar{\theta})k\theta_i > (1-\bar{\theta})k\bar{\theta}$$

using (4.2) and (4.4),

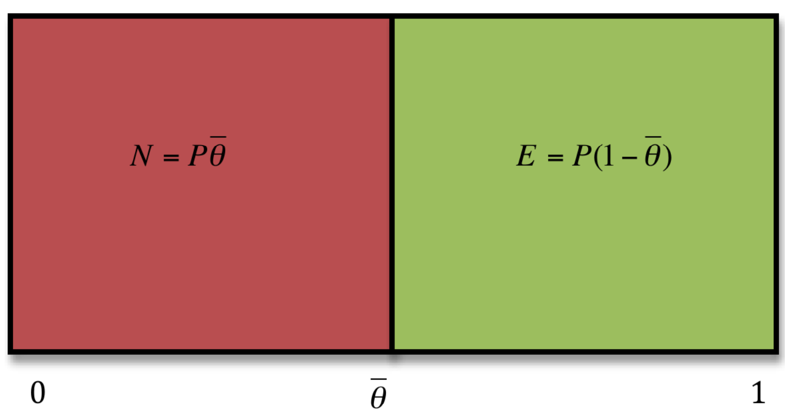
$$\bar{U}_N > U_N^i. \tag{4.10}$$

Thus, from (4.9) and (4.10),

$$U_E^i > \bar{U}_E = \bar{U}_N > U_N^i. \;\blacksquare \tag{4.11}$$

We can thus deduce that $P\bar{\theta}$ people choose not to be eco-friendly, and their preference parameters are distributed uniformly along the interval [0, $\bar{\theta}$). Similarly, $P(1-\bar{\theta})$ people will choose to be eco-friendly, and their preference parameters are uniformly distributed along ($\bar{\theta}$, 1]. We demonstrate this graphically in Fig. 4.1.1. The x-axis shows the uniform distribution of $\theta_i \in (0,1)$. The red box indicates individuals who choose to be eco-unfriendly while the green box indicates those who choose to be eco-friendly at any given $\bar{\theta}$.

Fig. 4.1.1. Distribution of Eco-friendly and Eco-unfriendly individuals



We thus identify three possible Nash equilibria; two pure and one mixed.

Equilibrium 1. Everyone is environmentally irresponsible.

Proof:

$$-Pn-(1-\theta_i)h < Pw-Pn$$

Therefore, using (4.1) and (4.2), we find that when the rest of the world is eco-unfriendly, *i*'s utility from being eco-unfriendly outweighs his utility from being eco-friendly. That is,

$$U_N^i > U_E^i . \blacksquare \qquad (4.12)$$

Equilibrium 2. $\bar{\theta} \in (0,1)$. Individuals for whom $\theta_i < \bar{\theta}$ will be eco-un friendly, while those for whom $\theta_i > \bar{\theta}$ will be eco-friendly.

Proof:

Using (4.6), (4.7), (4.8), (4.9), (4.10), (4.11),

$$\theta_i < \bar{\theta} \Rightarrow U_N^i > \bar{U}_N = \bar{U}_E > U_E^i$$

$$\theta_i > \bar{\theta} \Rightarrow U_E^i > \bar{U}_E = \bar{U}_N > U_N^i \ \blacksquare \qquad (4.13)$$

Equilibrium 3. Everyone is eco-friendly.

Proof:

$$Pw - (1-\theta_i)h > Pe - k\theta_i$$

Using (4.1) and (4.2), we find that when the rest of the world is eco-friendly, *i*'s utility from being eco-friendly outweighs his utility from being eco-unfriendly. That is,

$$U_E^i > U_N^i . \blacksquare$$

IV.2 Comparative Statics:

From (4.5), we arrive at the following results.

1. $\frac{\partial \bar{\theta}}{\partial h} < 0$. This has a rather complicated, but realistic interpretation. Holding all other exogenous variables constant, if the cost of engaging in eco-friendly behavior increases, then those who are already environmentally conscious will convince more people to behave in an eco-friendly manner. They do this in order to compensate for their increased costs. Therefore, although the comparative static seems perverse at first glance, it mirrors a phenomenon that manifests itself quite frequently in real life.

2. $\frac{\partial \bar{\theta}}{\partial k} > 0$. We can interpret this to mean that if societal disapproval of environmentally irresponsible behavior increases, those who are already eco-unfriendly try harder to convince others to join them in order to compensate for this surge in disapproval.

3. $\frac{\partial \bar{\theta}}{\partial w} < 0$. This result implies that as an individual's initial endowment increases, holding *x* constant, the proportion of the population that is eco-friendly increases. This can be interpreted to mean that if one additional eco-friendly individual can make a large positive difference to the environment, more people derive personal benefit from making the decision to be eco-friendly.

4. $\frac{\partial \bar{\theta}}{\partial x} > 0$. This implies that, holding *w* constant, an increase in *x,* and thus a decrease in personal contribution to the environment, decreases the number of eco-friendly individuals in the world. In other words, if the efficacy of one additional eco-friendly individual's environmental work declines, fewer

people will decide to be eco-friendly. They derive less personal benefit from this decision.

Our model demonstrates comparative static results similar to those in the two-person model. Although they seem perverse at first glace, within the context of our model, these results present an interesting and plausible interpretation of eco-friendly behavior.

IV.3 Social Welfare:

In this section we evaluate the efficiency of the Nash equilibria enumerated in section IV.1 in order to identify the outcome that most benefits both individual and society. Assuming that the marginal individual has a preference parameter of $\bar{\theta}$, using (4.1) and (4.2), we arrive at the following social welfare function:

$$W(\bar{\theta}) = P\bar{\theta}[P\bar{\theta}w + P(1-\bar{\theta})e - P\bar{\theta}n] - P(1-\bar{\theta})\left[\int_0^{\bar{\theta}} (\theta_i)d\theta_i\right]$$

$$+P(1-\bar{\theta})\left[P(1-\bar{\theta})x + P(1-\bar{\theta})e - P\bar{\theta}n\right] - \int_{\bar{\theta}}^{1}\left[(1-\theta_i)h\right]d\theta_i. \quad (4.15)$$

Consider individual and collective utility at each of the three categories of Nash equilibria we established in section IV.1.

Equilibrium 1. Everyone chooses to be eco-friendly.

Using (4.1), we find that each individual receives a utility of

$$U_E^i(\bar{\theta}=0) = Px + Pe - (1-\theta_i)h. \quad (4.16)$$

Therefore, using (4.15), the welfare of the entire population amounts to

$$W(\bar{\theta}=0) = P^2x + P^2e - \frac{h}{2}. \tag{4.17}$$

Equilibrium 2. $\bar{\theta} \in (0,1)$. Individuals for whom $\theta_i < \bar{\theta}$ will choose not to be eco-friendly, while those for whom $\theta_i > \bar{\theta}$ will not be eco-friendly.

Using (4.1), we find that eco-friendly individuals receive a utility of

$$U_E^i(\bar{\theta} \in (0,1)) = P(1-\bar{\theta})x + P(1-\bar{\theta})e - P\bar{\theta}n - (1-\theta_i)h, \tag{4.18}$$

while using (4.2), eco-unfriendly individuals receive a utility of

$$U_N^i(\bar{\theta} \in (0,1)) = P\bar{\theta}w + P(1-\bar{\theta})e - P\bar{\theta}n - P(1-\bar{\theta})k\theta_i. \tag{4.19}$$

Using (4.15), the world receives a utility of

$$W(\bar{\theta} \in (0,1)) = P^2(1-\bar{\theta})^2x + P^2\bar{\theta}w + P^2(1-\bar{\theta})e - P^2\bar{\theta}n - \int_0^{\bar{\theta}} P(1-\bar{\theta})k\theta_i d\theta_i - \int_{\bar{\theta}}^1 h(1-\theta_i)d\theta_i.$$

Therefore,

$$W(\bar{\theta} \in (0,1)) = P^2(1-\bar{\theta})^2x + P^2\bar{\theta}w + P^2(1-\bar{\theta})e - P^2\bar{\theta}n - P(1-\bar{\theta})k\frac{\bar{\theta}^2}{2} - h(1-\bar{\theta}) + h\frac{(1-\bar{\theta})^2}{2} \tag{4.20}$$

Equilibrium 3. Everyone chooses to be eco-unfriendly.

Using (4.2), we find that every individual derives a utility of

$$U_N^i(\bar{\theta}=1) = Pw - Pn, \tag{4.21}$$

and societal welfare, using (4.15), in this case would be

$$W(\bar{\theta}=1) = P^2w - P^2n. \tag{4.22}$$

Since we are characterizing a global phenomenon, we will consider the asymptotic case where $P \longrightarrow \infty$.

Claim 1: Every individual is best off when the entire world, including him or herself, is eco-friendly.

Proof:

As $P \longrightarrow \infty,$

$$Pn > (1-\theta_i)h \Rightarrow Pw - Pn < Pw - (1-\theta_i)h$$

$$\Rightarrow U_E^i(\overline{\theta}=0) > U_N^i(\overline{\theta}=1) \tag{4.23}$$

from (4.16) and (4.21). Also, it is clear from (4.16) and (4.18) that

$$Pw - (1-\theta_i)h > P(1-\overline{\theta})x + P(1-\overline{\theta})e - P\overline{\theta}n - (1-\theta_i)h$$

$$\Rightarrow U_E^i(\overline{\theta}=0) > U_E^i(\overline{\theta}\in(0,1)). \tag{4.24}$$

Similarly, from (4.16) and (4.21), as $P \longrightarrow \infty,$

$$Pw - (1-\theta_i)h > P\overline{\theta}w + P(1-\overline{\theta})e - P\overline{\theta}n - P(1-\overline{\theta})k\theta_i \tag{4.25}$$

$$\Rightarrow U_E^i(\overline{\theta}=0) > U_N^i(\overline{\theta}\in(0,1)).$$

From (4.23), (4.24) and (4.25), we can conclude that every individual is best off when the entire world makes a collective decision to behave in an eco-friendly fashion. ■

Claim 2: The world is best off when every individual in it is eco-friendly.

Proof:

From (4.15),

$$\frac{\partial^2 W(\overline{\theta})}{\partial \overline{\theta}^2} = 2P^2(x+w) + 3P\overline{\theta}k - Pk + h > 0.$$

Clearly, the interior solution to the first order condition is a minimum which indicates that the social welfare function has two local maxima at $\overline{\theta}=0$ and $\overline{\theta}=1$.

Using (4.15), we find that

$$W(\bar{\theta} = 0) > W(\bar{\theta} = 1).$$

This implies that it is best for society to collectively behave in an environmentally conscious fashion. ■

We have thus successfully demonstrated that even in a population of infinite types of people, universal environmental consciousness and activism is most beneficial to society and citizen alike. Further, we have shown that, the world is better off when everyone is not eco-friendly than it is when some are eco-friendly and some are not. In fact, social utility in the continuous model is minimized at the interior solution to the first order condition, $\frac{\partial W(\bar{\theta})}{\partial \bar{\theta}} = 0$. This is because when the society is thus divided in choice, environmentally irresponsible individuals ravage the environment with their wasteful ways. Simultaneously, eco-friendly individuals disapprove of this destructive behavior and cause their eco-unfriendly neighbors to suffer. As a result, societal welfare is severely diminished.

V. Conclusions

In this paper, we apply Kaushik Basu's model of self-perpetuating dictatorships (Basu, 1986) to the field of environmental economics. We construct a theoretical model of environmental behavior based on the assumption that an individual's decisions are motivated by the behavior of those around him. Given our assumptions, we demonstrate that it best for both individual and society as a whole if everyone in the world is eco-friendly.

In section III, we present the simplest version of this model in which we assume players to belong to one of two species. Individuals of each species choose to be eco-friendly or not. They base this decision on the number of people they expect to behave in a certain way. We define their "tipping-points" as the minimum number of people they must expect to be eco-friendly in order for them to choose to be eco-friendly themselves. This tipping-point, is influenced by a number of parameters. Most notably, when the cost of being eco-friendly increases, the tipping-point increases. Therefore, it is more difficult to convince an individual of either species to be eco-friendly. Similarly, when the consequences for eco-unfriendly behavior become more severe, the tipping-point decreases. That is, individuals are more easily convinced to use green practices.

In section IV, we demonstrate that we are able to generalize our two-type model to one with infinite species without altering our general conclusions. The tipping-point in this case takes on a different meaning. It is the proportion of the population that chooses not to be eco-friendly. We find that, when the price of eco-friendly behavior rises, a larger proportion of the population is eco-friendly. Similarly, when societal disapproval of non-green practices grows, a larger proportion of the population chooses not to be eco-friendly. We interpret this to mean that when the cost of one behavior increases, those who already practice this behavior convince others to join them. They do this in order to mitigate the increased costs.

In both models, there are three pure strategy Nash equilibria; everyone is eco-friendly, everyone is not eco-friendly, and an intermediate case. Both individual utility and social welfare are maximized at the Nash equilibrium where everyone is green. Interestingly, we find that it is better for the world if each individual is eco-unfriendly, than if a portion of its citizens are. We explain this result using Schelling's compatibility relation (Schelling, 1973). When everyone is eco-friendly, there is no one left to detract from the health of the environment. Similarly, when the entire world pollutes, there are no eco-warriors around to wag their fingers at this behavior. In the intermediate case, a portion of the population depletes environmental resources while everyone else admonishes them for this irresponsible behavior. Social welfare is thus diminished at this equilibrium. Thus homogeneity of choice is optimal for societal welfare.

Our results suggest that, if their aim is to maximize societal welfare, government agencies should strive to push individuals in the direction of universal eco-friendly behavior. They can do this by instituting policies that reduce individuals' tipping-points, and inflate their perception of the number of other eco-friendly people in the world. However, it should be impossible to achieve this ideal, in some cases, it would be better to aim for universal eco-unfriendliness than to settle for the intermediate case.

We recognize that there are obvious limitations to our model. Firstly, we assume that the contribution an eco-friendly individual makes to the public good is exogenously fixed. However, it may be more realistic to endogenize their donation. After all, people practice conservation to widely different degrees. Some simply recycle, while others dedicate their entire lives to rebuilding rainforests, or saving a species from extinction. Secondly, we only consider the games' pure strategy equilibria. It might be worthwhile to examine their mixed strategy equilibria, if any. Lastly, we make the rather strong simplifying assumption of a multiplicative psychological benefit. In most public goods games, the utility an individual derives from contribution is scaled down by some fraction

β between zero and one. It might be of interest to examine how, if at all, the results of this game are changed by introduction such a β.

VI. References and Related Reading

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