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Guido Buenstorf
Christian Cordes

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Max Planck Institute of Economics
Evolutionary Economics Group
Kahlaische Str. 10
07745 Jena, Germany
Fax: ++49-3641-686868

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Guido Buenstorf, Christian Cordes*

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Abstract

This paper shows how sustainable consumption patterns can spread within a population via processes of social learning even though a strong individual learning bias may favor environmentally harmful products. We present a model depicting how the biased transmission of different behaviors via individual and social learning influences agents' consumption behavior. The underlying learning biases can be traced back to evolved cognitive dispositions. Challenging the vision of a permanent transition toward sustainability, we argue that "green" consumption patterns are not self-reinforcing and cannot be "locked in" permanently.

Keywords: Consumer Behavior – Cultural Evolution – Learning – Sustainability – Evolutionary Economics

JEL Classifications: D11, D83, Q01, C61

* Buenstorf and Cordes (corresponding author): Max Planck Institute of Economics, Evolutionary Economics Group, Kahlaische Str. 10, 07745 Jena, Germany (e-mail: cordes@econ.mpg.de).

1. Introduction

Contemporary economies pose severe and potentially disastrous challenges to the natural environment. Ecological economics as a field has developed in reaction to these challenges. Its guiding vision is that of (ecological) sustainability: an aggregate pattern of economic activities that can be upheld over time without compromising the environment's capacity to support the needs of future generations (WCED, 1987; Sartorius, 2006).[2] As all economic activity is ultimately aimed at satisfying the needs and wants of consumers, consumer behavior has an essential role to play in any transition toward a more sustainable economy (see, e.g., Arrow et al., 2004; Brennan, 2006; Wagner, 2006; van den Bergh, 2007). To approach a sustainable state, consumers will have to reduce their level of consumption and/or modify the kinds of goods they consume.

Substantial prior work has focused on the aggregate level of individual consumption activity (Heiskanen and Pantzar, 1997; Røpke, 1999). However, it is unclear how reductions in the overall level of individual consumption can be induced. In the face of apparently insatiable human desires, a reduction based on voluntary restraint is unlikely to happen, particularly as long as productivity increases and technological innovation continually open up new consumption opportunities. Increasing incomes and innovation also limit the power of incentive-based instruments to reduce overall consumption, because monetary punishments such as eco-taxes would have to reach extremely high levels to remain effective. Finally, engineering a reduction in overall consumption by forced restraint obviously faces significant legitimacy issues.

The present paper thus re-focuses the attention on the composition of consumption activities, discussing whether and how consumer learning can shift consumption toward activities that are more sustainable in terms of the required inputs of resources and outputs of harmful emissions. For this purpose, we model the cultural transmission of consumer behavior via processes of individual and social learning. The model incorporates insights from evolutionary and behavioral economics, anthropology, and psychology. As will be shown, cultural transmission is biased; people tend to acquire some behavioral variants more easily than others. Moreover, this process of cultural transmission is influenced and constrained by humans' evolved psychology that shapes what we learn, how we think, and whom we imitate.

[2] The present discussion is restricted to the environmental dimension of sustainability, while its social and (narrowly) economic dimensions are eclipsed.

Consumer learning is critical for the diffusion of sustainable consumption patterns. We show how consumption of environmentally benign goods can spread within a population via processes of social learning even though a strong individual learning bias may favor an environmentally harmful substitute. However, our model also shows that "green" consumption patterns are not self-reinforcing and cannot be "locked in" permanently. This finding suggests that demand-oriented policy measures are limited in their potential to help achieve a more sustainable economy.

By building on insights from psychology and anthropology on how human behavior is conditioned by evolved needs and learning capacities, our approach contributes to the "naturalist" line of research in evolutionary economics (Witt, 2003; Cordes, 2007). We abandon the assumption that agents rationally choose utility-maximizing items from a given set of alternatives. Instead, we assume that people must learn which consumption goods meet their preferences well and that an important force in learning is social observation. Agents are aware of only a fraction of the available information. Limits to human rationality in the face of a complex world induce individuals to adopt culturally transmitted behaviors, frequently without independent evaluation of their outcomes. Therefore, imitating or learning from others is one of the most important means by which humans finesse the bounds of rationality (Boyd and Richerson, 1993; Richerson and Boyd, 2001).[3] This can lead to adaptive but also myopic choice among the behavioral variants observed.

The remainder of the paper proceeds as follows. In section 2, we sketch the evolutionary approach of analyzing consumer behavior as the outcome of individual and social learning. Section 3 discusses some implications of the evolutionary approach for a potential transition to sustainable consumption. In Section 4, we develop a model depicting how the biased transmission of different kinds of behavior via individual and social learning processes influence agents' consumption activities. Potential implications of the insights gained before for learning dynamics and "green" consumption behaviors are the subject matter of Section 5. Section 6 presents some considerations regarding environmental policy making. Section 7 concludes the paper.

[3] Rational choice is a weak process relative to cultural transmission in the construction of behavioral repertoires (for a similar argument see Eshel et al., 1998).

2. Consumption as a learning process

Recent theorizing in evolutionary economics studies consumer behavior as shaped by complex processes of individual and social learning. These learning processes originate from innate physiological needs and capacities of the human cognitive apparatus, including the capacity for culture (see especially Witt, 2001; Ruprecht, 2005; Cordes, 2004). In the following, we will refer to this theory as the *learning theory of consumption* (short: LTC). The predictions derived from it resonate with related work in anthropology (e.g., Henrich and McElreath, 2003; Corning, 2005).

LTC remains within the utilitarian tradition of economics. It suggests that acts of consumption are motivated by their capacity to fulfill human wants. In part, wants are innate and universally shared. Such innate wants correspond to basic physiological needs such as the intake of air, water and food, sleep, and the maintenance of the body temperature, but also more psychic needs such as entertainment and social recognition. Their ability to satisfy innate wants thus provides the most basic hedonistic motivation of consumption activities. Consumers are inclined to engage in activities, and purchase the corresponding goods and services, that help them satisfy their innate wants.

In addition to the set of innate wants, agents acquire further wants through processes of associative learning (conditioning through reinforcement). This want learning may operate in an entirely automatic way without conscious control (Witt, 2001). It takes place when initially neutral activities are repeatedly performed simultaneously with activities that satisfy pre-existing (and currently non-satiated) wants. Over time, an association is formed between the initially neutral activity and the rewarding experience from satisfying the innate want. A new want for the neutral activity and the related "inputs" (i.e., goods and services) is thus developed. Depending on their individual learning history shaped by the specificities of their exposure to stimuli and interaction with other agents, associative want learning enables humans to acquire highly idiosyncratic sets or chains of learned wants. Under conditions of affluence, the link between a specific acquired want and the original innate wants may often be quite indirect.

The learning capacities of human agents obviously go beyond simple associative learning based on conditioning (see Cordes, 2004), which is in similar forms also observable in animals. Consumer behavior is also informed by consciously controlled learning processes that lead to the acquisition of explicit knowledge (i.e., knowledge that is based on consciously processed information and can be verbalized) on the characteristics of goods as well as on how specific

activities and goods contribute to the satisfaction of wants (both innate and acquired). Importantly, this kind of learning does not require direct feedback provided by the senses.

LTC suggests that the associative and the consciously controlled levels of consumer learning systematically interact (Witt, 2001). Human attention to stimuli is selective, and available information is more likely to be consciously processed if it relates to activities for which a want already exists. In turn, exposure to information may induce further consumption activities. These initiate new processes of associative learning, thus furthering the evolution of the agent's want structure by reinforcing existing wants and possibly also adding new ones.

The acquisition of consumption knowledge is shaped by the information an agent is exposed to. Information availability is only to a minor extent within the control of the individual, for example, when she engages in deliberate search processes to find some information (e.g., when pondering purchases of expensive durables). The majority of consumption-related information available to an agent is determined by her social environment; it is the consequence of other agents' activities and communicative acts. Cultural conventions define what kinds of activities and communications are acceptable at a given time and location. Transmitted culture thus accounts for the bulk of variation in human consumption behavior.

As will be shown in detail, the socio-cultural environment is an important determinant of what information is available to an agent via various forms of cultural transmission. Variation of consumption practices is caused by communication in social groups as well as the mass media. Through their agenda-setting effect on the kind of information that an individual agent is exposed to, they exert a substantial influence on the acquisition of consumption knowledge. Social learning induces similarities in the mindsets and behaviors of individuals within communicating populations.

The provision of potential role models is a particularly powerful channel through which social groups and mass media exert an influence on individual behavior. From observing role models and adopting their successful behavior, human agents can learn from others even in the absence of direct verbal communication (Bandura, 1986, ch. 2). Anthropological evidence likewise indicates that the adoption of cultural traits is conditioned by the observable attributes of the individuals who exhibit the trait (Richerson and Boyd, 2005, p. 69; Harrington Jr., 1999). In human phylogeny, selection favored social learners who were able to evaluate potential models and copy the most successful among them, thereby saving the costs of individual learning (see also Rogers, 1983; Henrich and Gil-White, 2001; Labov, 2001). Hence, in model-based learning

there is a predisposition to imitate successful or prestigious individuals. In general, a *model-based bias* results if social learners use the value of a second character that characterizes a model (e.g. prestige) to determine the attractiveness of that individual as a model for the primary character (e.g. a certain consumption behavior). This method of evaluating different cultural variants is likely to be much less costly than directly evaluating these variants (Boyd and Richerson, 1985, p. 135).

The social environment's impact on individual consumer behavior is further increased through the important motivating role of social recognition. As was noted above, social recognition is one of the innate wants identified by LTC. Social recognition is by necessity dependent on how the social environment sanctions specific individual acts of consumption. The want for social recognition combines with what anthropologists refer to as the *conformist bias* (see, for an overview, Aronson et al., 2002, ch. 8; Kameda and Diasuke, 2002; Henrich, 2004; Richerson and Boyd, 2005, p. 120ff). If social learners use a conformist bias, they will discriminate against traits that are rare in their local population. This bias uses the commonness or rarity of a cultural variant as a basis for choice. Due to the conformist bias, agents pick the cultural variant that is used and accepted by most of the models in a population (see also Henrich and Boyd, 1998).

Conformist transmission belongs to the class of frequency-dependent biases and has been a simple heuristic that improves the chance of acquiring the locally favored cultural variant (Boyd and Richerson, 1985, p. 216ff; 1989).[4] Especially if the environment changes slowly and the information available to an individual is poor, a reliance on social learning evolves that favors a strong conformist tendency. In the face of a complex world, boundedly rational individuals often adopt culturally transmitted behaviors without independent evaluation of their outcomes (Richerson and Boyd, 2001). Therefore, the constrained psychological resources are a fundamental part of cultural evolution including the dissemination of consumption knowledge.

These powerful effects of the social environment on consumer learning limit the variability of individual consumer behavior. They do not imply, however, that changes cannot take place at the social level. Changes are most likely with regard to the supply of information, for example, via cultural role models. Over sufficient time horizons and/or with sufficiently strong individual

[4] Frequency-dependent biases occur if the probability that social learners acquire a variant depends nonlinearly on the frequency of the variant among the set of models.

re-evaluations (for example because of exogenous shocks such as natural disasters), also the social rewards for particular consumption activities are variable.

3. Implications of consumer learning for sustainable consumption

The evolutionary consumer learning dynamics suggested by LTC have important ecological implications (Buenstorf, 2007). In what follows, we focus on individual consumer activities that involve the purchase or use of some specific consumer goods and services. Goods (and services) are represented by a set of characteristics (Lancaster, 1966), some of which determine their environmental impact.

In this context, it is important to note that the vast majority of environmentally relevant characteristics are of a non-sensory nature; except for special and extreme cases, agents cannot experience these characteristics with their senses. Some classes of pollutants (such as radioactivity) are not perceptible for the human senses. In other cases, environmental impacts of consumption acts may be too indirect to be perceived. As a consequence, most environmentally relevant characteristics of goods and services cannot trigger sensory feedback. They are therefore irrelevant for the satisfaction of innate wants in consumption activities. For example, the level of CO_2 emitted by a heating system does not directly affect the consumer's sensory experience of the pleasant temperature it helps provide. Because of this non-sensory nature, environmentally relevant characteristics cannot motivate the adoption of the good by a consumer without prior learning.

Let us first consider associative want learning, which is typically not under the conscious control of the agent. As outlined in the previous section, humans are able to form complex chains of new wants through associative learning starting from innate wants. In this way, wants for the consumption of "green" products can also be formed. This requires that a good with favorable environmental characteristics has additional characteristics that are both sensorily perceptible and can be associated with an innate or previously acquired want, or that the good is consumed jointly with other satisfying goods and activities. Repeated consumption of the good may then establish a new acquired want that becomes increasingly less dependent on the initially experienced sensory stimulus.

Yet, as the environmentally relevant characteristics themselves cannot cause the rewarding sensory experience, the associative learning process has to rely on characteristics that are unrelated to the good's environmental impact. It is entirely blind to the environmentally relevant characteristics of goods and services. While it allows for the adoption of sustainable consumer behavior, it does not provide a channel for learning sustainable consumption *per se*. Environmentally benign consumption behavior has to be motivated by other, non-environmental dimensions of the involved goods and services. Once adopted, it can always be challenged by alternative behaviors that are more attractive in terms of these non-environmental characteristics. In other words, there is a *hedonistic bias* in consumer behavior: environmentally superior goods are easily crowded out by alternatives offering equally (or more) rewarding sensory experiences.

In contrast to associative want learning, the consciously controlled acquisition of explicit consumption knowledge about differences in the environmental impact of close substitutes may directly enhance the subjective attractiveness of the "green" product for an individual consumer.[5] For this to happen, the individual both needs to be aware of the differences, and she has to be convinced that benefits derive from them. These benefits may be related to the consumer's own wants, for example, because the "green" product promises health benefits that a less environmentally benign substitute does not have. Alternatively, individual consumer behavior may even be shaped by knowledge of favorable environmental benefits that yield no immediate benefits to the consumer herself, but only to others (or the unspecific "environment").

Individual acquisition of explicit knowledge about environmentally relevant goods characteristics is highly dependent on the agent's social environment. Over the past decades, "green" interest groups have been highly successful in putting environmental issues on the public agenda. This availability of information has enabled individual consumers to learn about the environmental impacts of their own activities, in particular if they were members of groups that discussed environmental issues. In addition, numerous agents have been willing to act as role models for sustainable consumption, and the environmental impact of their activities has become a relevant aspect of social recognition granted to agents. All these developments favored the cultural transmission of environmentally relevant consumption knowledge and the adoption of corresponding consumer behavior.

[5] Implicitly, the following discussion assumes that explicit consumption knowledge is effective as a motivator of consumer behavior. We thus abstract from the well-known problem that agents' activities may be inconsistent with their own knowledge and beliefs.

However, explicit consumption knowledge is not immune to incompatible new information. When the thrust of available – socially transmitted – information becomes adverse to the currently consumed good, an agent may be induced to change her assessment of it and to abandon its consumption in favor of a substitute. For example, information on the environmental impact of a good or corresponding behavior may no longer be invoked in the agent's consumption choices if relevant role models, social groups, or the media cease to pay attention to this aspect. Over time, the environmental dimension of the individual consumption knowledge will then lose its importance in informing the agent's consumption choices, particularly when at the same time more detailed information about other aspects of the good and its substitutes becomes more available.

As in the case of associative want learning, this suggests that explicit consumption knowledge is not able to permanently lock-in "green" consumer behavior. Consumers may learn how to behave in a sustainable way when making concrete choices, and this knowledge is likely to be retained at least over intermediate time horizons. Its importance in consumer behavior may nonetheless be eliminated by newly acquired knowledge about other product characteristics or by changed priorities of the social environment. Again, we therefore conclude that even if sustainable consumption patterns are adopted, individual behavior is not be locked into these behaviors, but a future transition away from the sustainable behaviors cannot be ruled out. The next section provides a formal analysis of these aspects of consumer behavior.

Summing up, our discussion indicates that individual learning processes are limited in their capacity to induce robust sustainable consumption activities (Buenstorf, 2007). In spite of its powerful role as a motivator of "hedonistic" consumer behavior more generally, associative want learning is inhibited by the largely non-sensory character of environmentally relevant product characteristics. In the acquisition of explicit consumption knowledge, there is more room for deliberative elements and thus for environmental considerations. However, the individual is constrained by the information available to her, and she is also subject to limitations to her effective autonomy imposed by the want for social recognition, which favors conformist behavior. These considerations imply that individual consumer behavior is strongly shaped by cultural transmission of information and social norms. Accordingly, in the remainder of this paper, we focus on the cultural dimension of consumer learning. In particular, we model the learning of environmentally benign consumer behavior through social role models and conformist transmission of cultural variants.

4. A model of evolving consumer behavior

To understand how consumption activities evolve in a population of interacting agents, we need to account for the processes that increase the frequency of some behavioral variants and reduce that of others. A complex interplay of such processes will constantly affect any population's consumption "culture". In this context, agents' behavioral repertoires are crucially influenced by processes of individual and social learning. This section illustrates how the above considerations can be translated into a stylized mathematical model (see, as points of origin, Cavalli-Sforza and Feldman, 1981; Boyd and Richerson 1985). To keep the model traceable, we aggregate all consumer learning into two basic processes, individual associative learning of new wants on the one hand and social learning of explicit consumption knowledge via cultural role models and conformist transmission on the other. We assume that consumer learning is ubiquitous and that the processes discussed in the previous sections operate as biases influencing *what* agents learn.

In general, cultural transmission biases are forces that arise because some psychological factors make agents more likely to adopt some cultural contents rather than others, thereby changing the frequency of the different types of cultural variants in the population. In this context, biases can consist of an innate component and/or a cultural component acquired in an earlier episode of social learning (Richerson and Boyd, 2005, p. 66).[6]

In line with the earlier discussion, the model analyzes the cultural transmission of knowledge related to a specific consumption activity for which two alternative variants a and b exist. These variants are assumed to differ in their environmental impact because of differences in the involved goods and services. Let a represent the "sustainable consumption behavior" and b the "hedonistic consumption behavior". The state of the population of consumers is determined by the frequency of agents with the variant a, labeled p. Now, the task is to find a recursion equation in discrete time that allows us to predict the frequency of p in the next stage of the cultural transmission process given its frequency in the present stage. Cultural transmission takes place between the members of a population. The general model is of the form

$$p_{t+1} = p_t + \textit{cultural evolutionary forces (biases)}.$$

[6] Each of these biases of cultural transmission arises from the attempts of social learners to evaluate the adaptiveness of the different cultural variants they are exposed to in a setting in which information is incomplete or costly to acquire (Boyd and Richerson, 1985). This does not imply that all biases are necessarily adaptive, especially in contemporary societies.

Specifically, we will focus on three cultural evolutionary forces that bias transmission: the hedonistic, role model, and conformity biases introduced above. They all can be traced back to evolved cognitive dispositions and operate at the individual or social level. We first derive partial recursions addressing these biases individually and then analyze the resulting aggregate learning dynamics.

Individual want learning

The discussion in the previous section has shown that associative want learning is of limited power to induce sustainable consumption activities, particularly if "hedonistic" substitutes exist that are not only more harmful to the environment but also have more attractive characteristics otherwise. In this case, a direct learning bias favoring the "hedonistic" variant results from this superiority.[7] Even a relatively weak direct bias can have important effects on the frequency of different cultural variants in a population (Richerson and Boyd, 2005, p. 69).

We reflect this possibility in the model by assuming that the probability of new adoption differs between the alternative behavioral variants (see Boyd and Richerson, 1980). Specifically, we assume that each a agent has a μ_{ab} chance of learning to favor the hedonistically attractive variant and each b consumer a μ_{ba} chance of learning to behave in a more sustainable way, where $\mu_{ab} >> \mu_{ba}$, i.e., the sensory pleasures connected to the hedonistic variant strongly bias the adoption dynamics in favor of this behavior.

To characterize the evolution of behavior in a group of consumers, the model must allow us to predict the changes in the frequency of the alternative variants over time. To do this, we must derive a recursion that determines p in the next time step, p', given the value of p in this period. Hence, the partial recursion for the individual learning phase is

$$p' = p + (1 - p)\mu_{ba} - p\mu_{ab}. \tag{1}$$

Social learning and the influence of cultural role models

For a consumer is normally not capable of sensorily experiencing the environmental impact of her consumption, the passing on of environmentally benign behaviors between agents is

[7] This process can be unconscious. See for an example of such a bias Cordes (2005b).

mainly subject to consciously controlled learning, which in turn is strongly affected by cultural transmission processes. Reflecting humans' evolved psychology, the social learning underlying the cultural transmission processes is biased; people tend to socially acquire some cultural variants rather than others. The model reflects the two biases of social learning that where discussed above, the role model bias and the conformity bias.

To allow the relevance of different models (e.g., individuals in different social roles) to differ, we assign different weights to them. We do this by specifying the probability that a particular set of role models makes an individual to acquire the behavioral variant a. The importance of the ith model, A_i, in this transmission process is defined by

$$A_i = \frac{\alpha_i\left(1+\frac{1}{2}D\right)}{\sum_{j=1}^{n}\alpha_j\left(1+\frac{1}{2}D\right)}. \tag{2}$$

Consequently, the actual weight of the ith model depends on (1) her basic weight α_i ($\sum_i \alpha_i = 1$) and (2) the commonness of her behavioral variant in the set of models, expressed by the frequency-dependent or conformity bias parameter D. We assume $0 < D \leq 1$, i.e., cultural transmission creates a force increasing the frequency of the more common variant in the group. Moreover, the weights given by (2) sum up to 1 and are normalized by the denominator so that A_i gives the weight of the ith model relative to the other models encountered by the individual in question. One of the cultural role models, M1, is assumed to always show behavior a, i.e., this agent or medium is exclusively exhibiting the environmentally benign consumption behavior. With these assumptions, the cultural transmission table showing the probability of agents acquiring behavior a or b given a particular set of cultural role models (M1, M2, M3) that have different total weights yields (see, for a similar approach, Boyd and Richerson, 1985, p. 209):

Table 1 The probability of agents acquiring consumption behavior a or b given a particular set of models (M1, M2, M3) that have different intrinsic weights (α_1, α_2, α_3) and frequency-dependent cultural transmission (bias parameter D).

Behavioral Variant of			Probability That Agent Acquires Behavioral Variant	
M1	M2	M3	a	b
a	a	a	1	0
a	a	b	$\frac{(\alpha_1+\alpha_2)\left(1+\frac{1}{2}D\right)}{1+\frac{1}{2}D(1-2\alpha_3)}$	$\frac{\alpha_3\left(1-\frac{1}{2}D\right)}{1+\frac{1}{2}D(1-2\alpha_3)}$
a	b	a	$\frac{(\alpha_1+\alpha_3)\left(1+\frac{1}{2}D\right)}{1+\frac{1}{2}D(1-2\alpha_2)}$	$\frac{\alpha_2\left(1-\frac{1}{2}D\right)}{1+\frac{1}{2}D(1-2\alpha_2)}$
a	b	b	$\frac{\alpha_1\left(1-\frac{1}{2}D\right)}{1+\frac{1}{2}D(1-2\alpha_1)}$	$\frac{(\alpha_3+\alpha_2)\left(1+\frac{1}{2}D\right)}{1+\frac{1}{2}D(1-2\alpha_1)}$

For example, let $P(a|aab)$ denote the conditional probability that a consumer acquires variant a given that she is exposed to models with variants a, a, and b. Then, from the table, the frequency of a after transmission, p'', given that is was p' before transmission, is

$$p'' = p'^2 + p'(1-p')\{P(a|aab) + P(a|aba)\} + (1-p')^2\{P(a|abb)\}. \quad (3)$$

This term computes the frequency of each different set of social models, multiplies this by the probability that a particular set of social models results in an individual acquiring a particular variant, and then sums over all possible sets of social models. Note that we assume model M1 to show behavior a all the time. As is shown in the appendix, inserting the conditional probabilities from Table 1, we can rewrite this equation as follows:

$$p'' = p'^2 + (p'-1)^2(\alpha_1 + D\alpha_1(\alpha_1-1)) + p'(p'-1)(\alpha_2+\alpha_3-2+D(\alpha_2(\alpha_2-1)+\alpha_3(\alpha_3-1))). \quad (4)$$

To keep the model traceable, we assume that the two social models M2 and M3 have the same weights in the transmission process, i.e., we assume $\alpha_2 = \alpha_3$. Furthermore, α_1 is then given by $1-2\alpha_3$. Therefore, equation (4) simplifies to

(4a) $$p'' = 1 + 2\alpha_3\left(p' - 1\right)\left(1 + D - 2D\alpha_3 + Dp'\left(3\alpha_3 - 2\right)\right).$$

Combining individual and social learning

The complete recursion for p, obtained by substituting (1) into (4a) is expressed as

(5) $$p'' = 1 + 2\alpha_3\left(p + \mu_{ba}\left(1-p\right) - p\mu_{ab} - 1\right)\left(1 + D - 2D\alpha_3 + D\left(3\alpha_3 - 2\right)\left(p + \mu_{ba}\left(1-p\right) - p\mu_{ab}\right)\right).$$

For the purpose of further simplification, we assume a positive value for μ_{ab} while setting $\mu_{ba} = 0$ in the following. This implies that individual learning exclusively favors behavioral variant b. As regards the learning dynamics of the model, this is the theoretically most interesting case. We thus obtain

(5a) $$p'' = 1 + 2\alpha_3\left(1 + p\left(\mu_{ab} - 1\right)\right)\left(D\left(2\alpha_3 - 1 + p\left(3\alpha_3 - 2\right)\left(\mu_{ab} - 1\right)\right) - 1\right).$$

This recursion models the change of p in the population over one individual and one social learning step. By setting the parameters of the system, we can analyze its long run behavior by conceptually iterating equation (5a) recursively for many generations. Moreover, we can now calculate the equilibrium frequency of the cultural variant a in the population. At equilibrium the population does not change so $p'' - p = 0$. We subtract p from both sides of (5a). One can determine the equilibrium of the set of coupled recursions implied by (5a) by solving for $\hat{p}$ denoting the equilibrium frequency of the sustainable consumption behavior a:[8]

[8] There is a second solution for $\hat{p}$ that yields negative values and is therefore ignored in this context. The equilibria denoted by $\hat{p}$ and given by equation (6) are stable (see appendix).

(6)

$$\hat{p} = -\frac{1}{4\alpha_3(3\alpha_3-2)D(\mu_{ab}-1)^2}(2\alpha_3(D(5\alpha_3-3)-1)(\mu_{ab}-1)+$$
$$\sqrt{4\alpha_3(\mu_{ab}-1)((1-\alpha_3)((\alpha_3-1)D+1)(D\alpha_3+1)+(D^2\alpha_3(\alpha_3-1)^2+2(\alpha_3(\alpha_3-4)+2)D+\alpha_3)\mu_{ab})+1}-1$$

.

Although it is not easy to interpret this complex term, we can gain some insights on the learning dynamics underlying the model. As is indicated by the derivative of (6) with respect to α_3, the weight of the cultural role models M2 and M3 ($\alpha_2 = \alpha_3$), $\frac{\delta\hat{p}}{\delta\alpha_3}$ (see appendix), the equilibrium share of agents that stick to the environmentally benign consumption behavior, $\hat{p}$, is always decreasing in α_3.[9] Figure 1 below plots the values of $\frac{\delta\hat{p}}{\delta\alpha_3}$ for different values of α_3 ($0 < \alpha_3 \leq 0.5$) and μ_{ab} ($0 \leq \mu_{ab} < 1$) for a given conformity bias of $D = 0.5$. The decrease in $\hat{p}$ is strongest when the variance in the distribution of a and b behaviors in the population is high, i.e., when there are many pairings of models holding different behaviors. This is indicated by the "deep valley" on the right hand side of figure 1. Given the fact that M1 is always showing behavior a, the number of behavior b-types among the other role models crucially depends on the hedonistic learning bias μ_{ab} favoring behavior b.

[9] With the only exception being the case when $\mu_{ab} = 0$. Then $\frac{\delta\hat{p}}{\delta\alpha_3} = 0$ for all α_3.

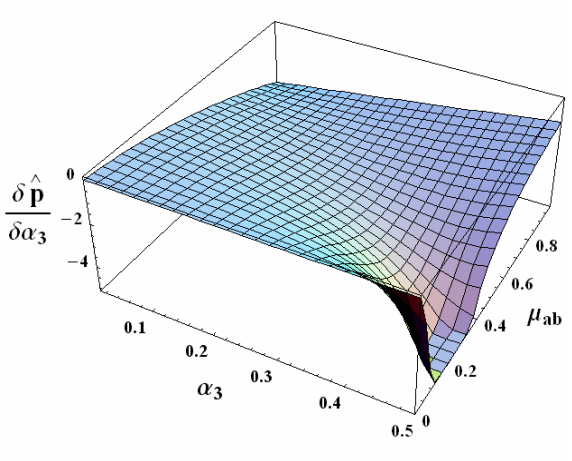

Figure 1: Values of $\frac{\delta \hat{p}}{\delta \alpha_3}$ for $D = 0.5$, $0 < \alpha_3 \leq 0.5$, and $0 \leq \mu_{ab} < 1$.

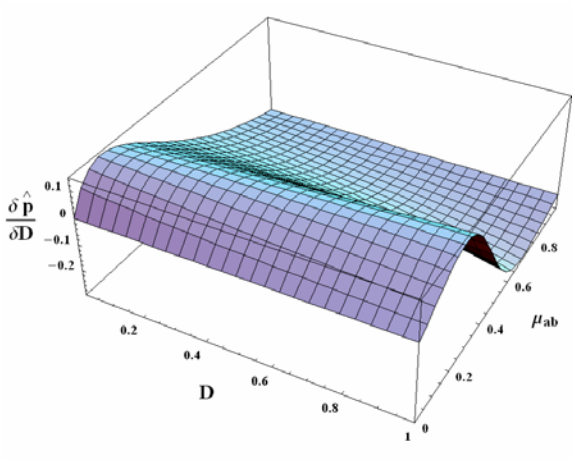

Figure 2: Values of $\frac{\delta \hat{p}}{\delta D}$ for $\alpha_3 = 0.3$, $0 < D \leq 1$, and $0 \leq \mu_{ab} < 1$.

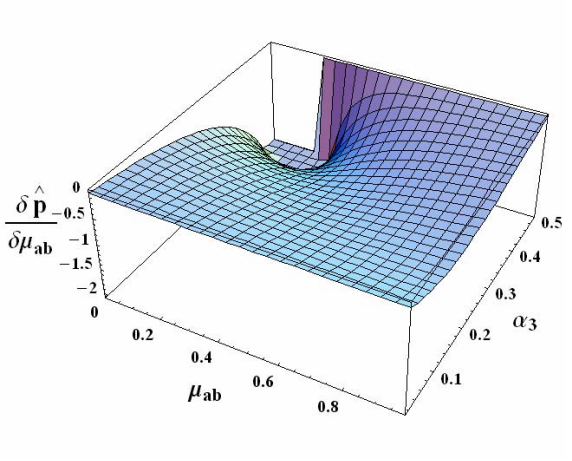

Figure 3: Values of $\frac{\delta \hat{p}}{\delta \mu_{ab}}$ for $D = 0.5$, $0 \leq \mu_{ab} < 1$, and $0 < \alpha_3 \leq 0.5$.

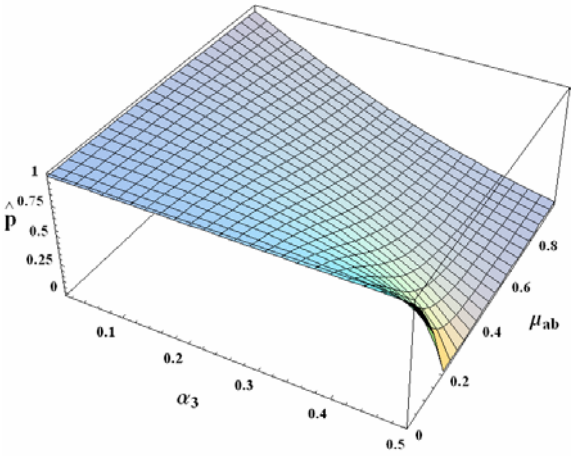

Figure 4: Equilibrium values for $\hat{p}$ ($D = 0.5$).

For low values of α_3 and μ_{ab}, the rates of change of $\hat{p}$ when the parameters change, i.e., the differences between the single equilibrium states, are low. Due to the fact that $\alpha_1 = 1 - \alpha_2 - \alpha_3$ and $\alpha_2 = \alpha_3$, a rising weight of M2 and M3 implies a lower influence of M1 in cultural transmission. This enables the b behavior to spread within the population and gain a higher share via b-types among M2 and M3 introduced by the hedonistic learning bias μ_{ab}. On the other

hand, low values for α_2 and α_3 entail a great influence of role model M1, the model that is assumed to always exhibit the environmentally benign behavior, giving rise to a higher share of behavior a in the group.

The derivative of (6) with respect to D, $\frac{\delta\hat{p}}{\delta D}$ (see appendix), shows that $\hat{p}$ increases when μ_{ab} is low and then decreases rapidly when μ_{ab} exceeds a certain threshold. The higher the conformity bias D, the steeper is this decline. Figure 2 gives the values of $\frac{\delta\hat{p}}{\delta D}$ for different values of D $(0 < D \leq 1)$ and μ_{ab} $(0 \leq \mu_{ab} < 1)$ assuming that the weights of the models M2 and M3 are $\alpha_2 = \alpha_3 = 0.3$. If the learning bias μ_{ab} is high, then the conformity bias D favors the spread of consumption behavior b. This is due to the fact that in this case an individual encounters many model constellations that are composed of more b than a models. On the other hand, given a small hedonistic bias, the conformist transmission increases the frequency of the sustainable behavior a in the population because the model M1 is always a in addition to some a models among the models M2 and M3, which results in many pairings with more a models.

Figure 3 above plots the derivative of (6) with respect to μ_{ab}, $\frac{\delta\hat{p}}{\delta\mu_{ab}}$ (see appendix), for different values of μ_{ab} $(0 \leq \mu_{ab} < 1)$ and α_3 $(0 < \alpha_3 \leq 0.5)$ assuming $D = 0.5$. The term $\frac{\delta\hat{p}}{\delta\mu_{ab}}$ again reflects the effects of a high variance among the role models in combination with an increasing influence of the cultural role models M2 and M3 (see the “deep valley” in the upper left corner of figure 3). The equilibrium frequency of a, given by $\hat{p}$, is decreasing in μ_{ab} (for $0 < \alpha_2, \alpha_3 < 0.5$). High values of μ_{ab} imply a low number of agents that potentially switch between behaviors and therefore small differences between the states of equilibrium.

5. Learning dynamics and “green” consumption

It is possible to derive some insights concerning agents’ consumption behavior from the model developed in the preceding section. Equation (6) – denoting the equilibrium frequency of the environmentally benign behavior a – shows that a prominent cultural role model with a sufficiently large weight in the cultural transmission process can offset even a strong hedonistic

learning bias and maintain a high level of "green" consumption behavior within a population. To see this, figure 4 visualizes the values for $\hat{p}$ depending on α_3 and μ_{ab} given a conformity bias $D = 0.5$ favoring the more common cultural variant among the role models. If the influence of the "green" role model M1 decreases, i.e., when α_2 and α_3 increase ($\alpha_1 = 1 - \alpha_2 - \alpha_3$; $\alpha_2 = \alpha_3$), while μ_{ab} introduces some b-type consumers, the level of sustainable consumption behavior in the population decreases. On the other hand, facing a large individual learning bias μ_{ab}, a high frequency of behavior a can nevertheless be maintained in the population if the influence of M1, measured by α_1, in cultural transmission is high.

> *Proposition 1*: Social learning can overcome strong direct biases in cultural transmission. As a consequence, social models exhibiting environmentally benign behaviors can establish a "green" consumption regime notwithstanding a strong hedonistic bias in individual learning that favors harmful consumption behavior.

For this to happen, a high weight of the a-model M1 is necessary. However, when the influence of this role model is low and the direct learning bias μ_{ab} is high, social learning may not be suitable to overcome whatever initial hedonistic disadvantages consumption behavior a may entail compared to behavior b (for example, in terms of convenience).

By iterating the complete recursion for p, given by equation (5a), for many learning steps, we gain some additional insights on the learning dynamics leading to the equilibrium values of p, $\hat{p}$, calculated by equation (6) and shown in figure 4. If, for example, the weight of α_3 is close to 0.5, which implies a very small influence of the "green" cultural role model M1, and the hedonistic bias, μ_{ab}, is near zero, then behavior a can still spread within the population, as is shown by figure 5. This is due to the fact that there are also a-types among the models M2 and M3 that, together with the conformity bias D, cause the spreading of the "green" behavior a within the population.

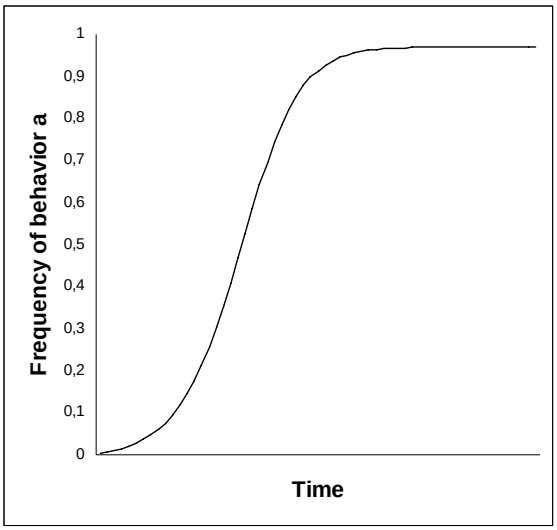

Figure 5: The diffusion of behavior a given that $\alpha_3 = 0.4975$, $\mu_{ab} = 0.01$, $D = 0.5$, and $p = 0$ in the beginning.

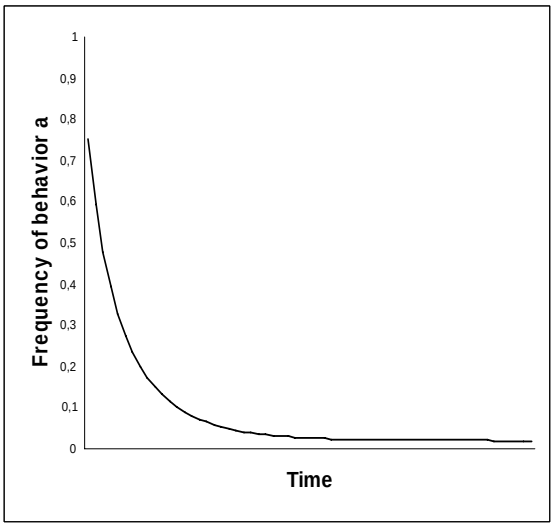

Figure 6: The decrease of behavior a given that $\alpha_3 = 0.4975$, $\mu_{ab} = 0.3$, $D = 0.5$, and $p = 1$ in the beginning.

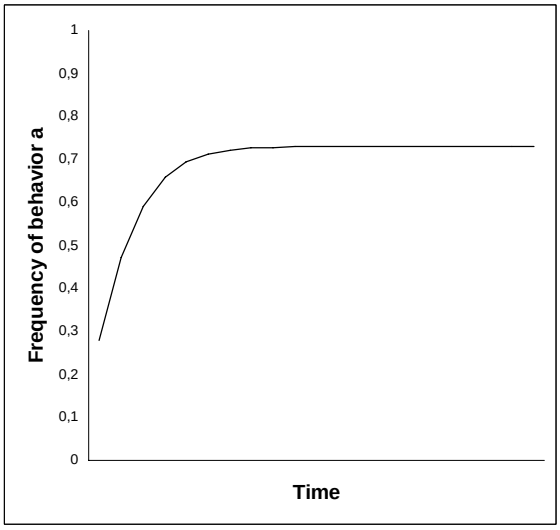

Figure 7: The diffusion of behavior a given that $\alpha_1 = 0.4$, $\mu_{ab} = 0.3$, $D = 0.5$, and $p = 0$ in the beginning.

However, *ceteris paribus*, as soon as the hedonistic learning bias increases, thereby introducing some more b-variants to the population, the frequency of a decreases steeply, as can

be seen in figure 6 ($\mu_{ab} = 0.3$).Therefore, the introduction of a hedonistically especially attractive alternative variant may threaten an established "green" consumption regime.

> *Proposition 2*: The more hedonistically attractive a certain behavior is, the stronger is the direct learning bias favoring this behavior. *Ceteris paribus*, this cultural variant then disseminates within a population more easily. This implies that "green" consumption patterns cannot be "locked in" permanently.

Proposition 2 captures the difficulties of diffusion for environmentally superior consumption activities that are hedonistically disadvantaged, for example, because of their relative inconvenience (think of power tools versus hand-driven alternatives, or motor traffic versus bicycles or walking). For instance, driving fast cars may be hedonistically rewarding for many people for it potentially meets some basic wants: it provides an effortless, convenient, and prestigious means of mobility.[10] What is more, it offers many opportunities for associative learning of new wants. For these reasons, hedonistically less attractive alternative means of transportation, such as trains or trams, suffer from a potential relative disadvantage as to their adoption probability. Explicit knowledge regarding their relative environmental friendliness may however act against this preference (see also Jackson, 2002).

Another implication derived from the equilibrium values of $\hat{p}$ and their determinants concerns the role of the conformity bias D.

> *Proposition 3*: A conformity bias stabilizes an established "green" consumption regime if the majority of role models in the set of cultural models show environmentally benign behaviors. On the other hand, if the environmentally harmful consumption behavior is more common among the role models, this bias hinders the spreading of sustainable consumption patterns.

When agents observe only the hedonistically motivated behavior among their peer groups, it is more difficult to disseminate the environmentally benign behavior in this population via a "green" role model. If, for example, the "green" consumption behavior is propagated by the media (model M1) while – due to the hedonistic learning bias – most M2 and M3 cultural role models (e.g. an individual's peer group) exhibit the unsustainable behavior b, the conformity bias favors this environmentally harmful cultural variant. On the other hand, the conformity bias creates a bigger "plateau" in figure 4 that comprises high values of $\hat{p}$. In this case, most pairings of cultural models comprise more environmentally benign a-types than b-types and thus the conformity bias impedes the spreading of the harmful behavior b.

[10] For one of these underlying wants – the want for ease – see Cordes (2005a).

Individual preferences are – to a large extent – shaped by culture, social norms, mass media, advertisement, etc. Social influences tend to stabilize individual behavior in instances where an agent's hedonistic learning would induce changes in her consumption activities. In terms of our model and taking the situation depicted in figure 6 as a starting point, consider an increase in the weight of the role model M1, α_1 ($\alpha_1 = 1 - \alpha_2 - \alpha_3$), for example, the media that propagate the environmentally benign behavior a. Then the frequency of a – given a high value for the hedonistic bias μ_{ab} (0.3) – can nevertheless reach a high share in the population (see figure 7).

6. Implications for environmental policy making

Patterns of consumption are mostly established by cultural evolution based on social learning within populations, implying that individual learning processes alone are insufficient to explain the attained consumption regimes. However, none of the learning dynamics discussed here can permanently fix a high share of environmentally benign consumer choices. Based on our theoretical considerations and model results, it cannot be expected that the different forms of consumer learning consistently shift consumption patterns into the same "direction." Accordingly, even if more environmentally benign consumer choices have been observed for some time in a population, this does not rule out that consumers start to opt for less "green" substitutes in the future – an important aspect to be taken into account in environmental policy making. The nature of human learning is too flexible, and the effect of aggregate environmental problems on individual consumer behavior is too indirect, for learning to uniformly favor sustainability.

A "green" consumption regime that has been established in a population via processes of social learning does not "lock in"; it is not immune to changes in the strengths of the alternative biases affecting consumer behavior. For example, if the weight of the "missionary" role model M1 decreases in the cultural transmission process, the hedonistic variant will increase its share in a population of consumers, i.e., a lower $\hat{p}$ is reached by the learning dynamics (see figure 4). Such a lowering of a model's weight could be due to, for example, new information affecting her credibility and reputation. Alternatively, demographic changes may reduce the prestige of some role models as new generations of consumers enter the market. This result of the model suggests that the lasting adoption of (more) sustainable consumption activities in a population cannot be

taken for granted. Continual efforts at providing convincing role models may be required to maintain the prevalence of these activities.

In addition, potential new substitutes with characteristics that are better suited to provide satisfying hedonistic sensory experiences, implying a high value of μ_{ab}, constitute a permanent hazard to "green" consumer goods activities. Where explicit consumption knowledge has been acquired, it may be challenged by contradictory new information, or its relevance for actual consumption activities may decay as new information increasingly relates to aspects of the good (and its substitutes) other than its environmental impact. In principle, the appearance of more attractive hedonistic variants is beneficial to the consumer, so trying to prevent them or restricting the flow of information about these goods and services seems a policy of questionable legitimacy. However, availability of new substitutes may justify policy efforts aimed at enhancing the performance of the sustainable product variants, such as targeted procurement, to limit and possibly reduce the hedonistic "distance" between alternatives. Systematic provision of environmentally relevant information, such as mandatory information on resource and energy intensity of products (eco-labeling), may also be justified on these grounds. Finally, from the perspective of the present paper, monetary policy instruments such as eco-taxes may be useful to limit the disadvantages of environmentally superior goods and services.

Social influences operating through the conformity bias tend to have a stabilizing effect on individual consumption. But, as indicated by the model, conformity is a double-edged sword: while it helps to stabilize adopted sustainable behaviors, it also makes their initial adoption more difficult. Moreover, once a population of interacting agents overcomes the conformity bias because a "critical mass" (see Witt, 1997) of agents shifts in their evaluation of consumption acts, the information "on the agenda", or the prestige of certain cultural role models, new patterns of consumption may be adopted in a rather sudden way. This effect is captured by the steep "slope" in figure 2. It does not only complicate the management of consumer behavior, but may also increase the environmental hazards caused by consumption, as there is less time to regulate activities and/or offset their effects.

It is often suggested that, provided there is sufficient consumer demand, producers will voluntarily modify their products and processes to make them more compatible with sustainable development. In this view, the indirect effects of consumer behavior on the supply side of markets can be trusted to achieve some of the required changes in economic activities (see also Brennan, 2006). As a consequence, it is expected that less drastic policy interventions into the

supply side of markets may be required to attain given goals, and that the acceptability of these interventions can be enhanced. Moreover, since technological change is often cumulative in nature (Dosi, 1982; Nelson and Winter, 1982), even a temporary impact on consumer behavior may have permanent effects because of the innovations it induces.[11] Our analysis does not contradict any of these conjectures. However, even in the stylized model we presented above, diffusion of sustainable patterns of consumption depended on the complex interplay of several forces, and it could not be established once and for all. This suggests that for consumer-oriented policy measures to be successful, a thorough understanding of the cultural learning dynamics underlying evolving consumption patterns is required.

7. Conclusions

Evidence from psychology, evolutionary anthropology, and cognitive science suggests that humans have an evolved psychology that shapes what we appreciate, learn, and propagate (see Richerson and Boyd, 2005, p.4). Our cognitive dispositions influence the kinds of cultural variants, for example, different consumption behaviors, that spread and persist within a population. Moreover, these findings can substantiate assumptions on the evolution of consumption behavior and contribute to a theory of consumption. This paper has shown how environmentally benign consumption patterns can disseminate among agents via processes of cultural learning even if strong hedonistic biases favor environmentally harmful ways of consumption. A model of cultural transmission has been proposed that indicates conditions under which a "green" consumption regime can be maintained in the course of an evolutionary process. We see this model as a first step toward an applied science of cultural evolution in a consumption context.

A key conclusion is that in spite of inertial tendencies due to a conformist bias, consumer learning does not "lock in" wants and consumer knowledge such that once agents begin to adopt more environmentally benign patterns of consumption, they necessarily remain on this "path" toward sustainability. Hedonistically attractive new variants may be able to crowd out the established "green" behavior. This result runs counter to the widespread notion of a "transition"

[11] Consumer-oriented policies nonetheless cannot substitute for more fundamental policies such as the establishment of an adequate institutional and regulatory framework as well as the internalization of external effects through property rights and pricing.

toward sustainability. We consider it an important caveat against a too one-sided and optimistic outlook on the future. In particular, it entails the necessity to safeguard improvements in the sustainability of economic activities, which calls for ongoing and sometimes even increased policy attention, rather than taking for granted what has once been achieved.

In line with our argument, there is ample qualitative evidence of agents and cultures abandoning sustainable behaviors they once had adopted. However, to evaluate the importance of such shifts away from sustainability, the dynamics of (non-) sustainable consumer behavior have to be studied more thoroughly in quantitative empirical research. To address it by practical environmental policy making, we moreover have to learn more about the conditions such changes take place and how they can be affected.

Appendix

- Derivation of the conditional probabilities: let $P(a|aab)$ denote the conditional probability that an individual acquires the cultural variant a given that she is exposed to models with variants a, a, b. Then from Table 1

(A1) $$P(a|aab)=\frac{(\alpha_1+\alpha_2)\left(1+\frac{1}{2}D\right)}{1+\frac{1}{2}D(1-2\alpha_3)}.$$

If D is small enough to ignore terms of order D^2, then, after some simplifications,

(A2) $$P(a|aab)\approx 1-\alpha_3+D\alpha_3-D\alpha_3^2.$$[12]

An analogous derivation yields the expression for $P(a|aba)$. The sum of these two terms is

(A3) $$P(a|aab)+P(a|aba)=2+\alpha_2(D-1)-D\alpha_2^2+\alpha_3(D-D\alpha_3-1).$$

Due to the symmetry of the model, $P(a|abb)=1-P(a|baa)$. Thus

(A4) $$P(abb)=\alpha_1+D\alpha_1(\alpha_1-1).$$

The combination of these conditional probabilities yields equation (4) in the text.

- Proving the stability of the equilibrium at $\hat{p}$ (equation (6)): the value of the derivative of the complete recursion (equation 5a) with respect to p when $p=\hat{p}$ is

[12] This simplification does not alter the qualitative properties of the recursion derived in the text.

(A5)
$$\frac{\delta p''}{\delta p}\Big|_{\hat{p}} = 2\alpha_3(\mu_{ab}-1)\left(D\left(\frac{5\alpha_3+2(3\alpha_3-2)(\mu_{ab}-1)-3-2\alpha_3((5\alpha_3-3)D-1)(\mu_{ab}-1)+\sqrt{4\alpha_3(\mu_{ab}-1)\left((1-\alpha_3)((\alpha_3-1)D+1)(\alpha_3D+1)+\left((\alpha_3-1)^2\alpha_3D^2+2((\alpha_3-4)\alpha_3+2)D+\alpha_3\right)\mu_{ab}\right)+1}-1}{4(3\alpha_3-2)D(\mu_{ab}-1)^2\alpha_3}\right)-1\right).$$

This value is less than 1 and greater than -1 for $0 \le \mu_{ab} < 1$, $0 < \alpha_3 \le 0.5$, and $0 < D \le 1$, the relevant ranges of parameters in this context. Thus, the equilibrium is stable.

- The derivatives of $\hat{p}$ (equation (6)) with respect to α_3, D, and μ_{ab} are:

(A6)
$$\frac{\delta\hat{p}}{\delta\alpha_3} = \frac{1}{4(2-3\alpha_3)^2\alpha_3{}^2D(\mu_{ab}-1)^2}\left(\begin{array}{l}-2\alpha_3(3\alpha_3-2)(\mu_{ab}-1)\\ \left(\frac{5D\alpha_3+D(5\alpha_3-3)+4D^2(\mu_{ab}-1)\alpha_3{}^3-6(D-1)D(\mu_{ab}-1)\alpha_3{}^2+2(D(D(\mu_{ab}-1)-8\mu_{ab}+3)+\mu_{ab}-1)\alpha_3+D(4\mu_{ab}-1)+1}{\sqrt{4\alpha_3(\mu_{ab}-1)\left((1-\alpha_3)((\alpha_3-1)D+1)(D\alpha_3+1)+\left((\alpha_3-1)^2D^2\alpha_3+2((\alpha_3-4)\alpha_3+2)D+\alpha_3\right)\mu_{ab}\right)+1}}-1\right)+\\ 3\alpha_3\left(\frac{2\alpha_3((5\alpha_3-3)D-1)(\mu_{ab}-1)+\sqrt{4\alpha_3(\mu_{ab}-1)\left((1-\alpha_3)((\alpha_3-1)D+1)(D\alpha_3+1)+\left((\alpha_3-1)^2D^2\alpha_3+2((\alpha_3-4)\alpha_3+2)D+\alpha_3\right)\mu_{ab}\right)+1}-1\right)+\\ (3\alpha_3-2)\left(\frac{2\alpha_3((5\alpha_3-3)D-1)(\mu_{ab}-1)+\sqrt{4\alpha_3(\mu_{ab}-1)\left((1-\alpha_3)((\alpha_3-1)D+1)(D\alpha_3+1)+\left((\alpha_3-1)^2D^2\alpha_3+2((\alpha_3-4)\alpha_3+2)D+\alpha_3\right)\mu_{ab}\right)+1}-1\right)\end{array}\right)$$

(A7)
$$\frac{\delta\hat{p}}{\delta D} = \frac{1-2\alpha_3(\mu_{ab}-1)\left(\frac{D+\alpha_3((2\alpha_3-3)D+2)-2(\alpha_3+((\alpha_3-4)\alpha_3+2)D)\mu_{ab}+\sqrt{4\alpha_3(\mu_{ab}-1)\left((1-\alpha_3)((\alpha_3-1)D+1)(\alpha_3D+1)+\left((\alpha_3-1)^2\alpha_3D^2+2((\alpha_3-4)\alpha_3+2)D+\alpha_3\right)\mu_{ab}\right)+1}-2}{\sqrt{4\alpha_3(\mu_{ab}-1)\left((1-\alpha_3)((\alpha_3-1)D+1)(\alpha_3D+1)+\left((\alpha_3-1)^2\alpha_3D^2+2((\alpha_3-4)\alpha_3+2)D+\alpha_3\right)\mu_{ab}\right)+1}}-1}{4\alpha_3(3\alpha_3-2)D^2(\mu_{ab}-1)^2}$$

(A8)
$$\frac{\delta\hat{p}}{\delta\mu_{ab}} = \frac{1}{2\alpha_3(3\alpha_3-2)D(\mu_{ab}-1)^3}\left(\begin{array}{l}2\alpha_3((5\alpha_3-3)D-1)(\mu_{ab}-1)-\alpha_3\\ \left((5\alpha_3-3)D+\frac{-5D+\alpha_3\left(D\left(-2D(\alpha_3-1)^2-4\alpha_3+11\right)-2\right)+2\left((\alpha_3-1)^2\alpha_3D^2+2((\alpha_3-4)\alpha_3+2)D+\alpha_3\right)\mu_{ab}+1}{\sqrt{4\alpha_3(\mu_{ab}-1)\left((1-\alpha_3)((\alpha_3-1)D+1)(\alpha_3D+1)+\left((\alpha_3-1)^2\alpha_3D^2+2((\alpha_3-4)\alpha_3+2)D+\alpha_3\right)\mu_{ab}\right)+1}}-1\right)\\ (\mu_{ab}-1)+\sqrt{4\alpha_3(\mu_{ab}-1)\left((1-\alpha_3)((\alpha_3-1)D+1)(\alpha_3D+1)+\left((\alpha_3-1)^2\alpha_3D^2+2((\alpha_3-4)\alpha_3+2)D+\alpha_3\right)\mu_{ab}\right)+1}-1\end{array}\right)$$

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