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STIRPAT for marketing: An introduction, expansion, and suggestions for future use

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ABSTRACT

Prior consumer research has emphasized the importance of understanding the macro impact of consumer consumption on the environment. However, at this time, no tool exists to quantify the level and/or trajectory of that impact. Therefore, the purpose of this research is threefold: first, to introduce the STIRPAT model to the marketing industry; second, to begin its expansion; and third, to provide suggestions for future use of the STIRPAT in the field of marketing. The STIRPAT model is traditionally defined as the stochastic (ST) estimation of environmental impacts (I) by regression (R) on population (P), affluence (A) and technology (T). We expand the PAT aspect of the model to include additional elements of consumer behavior such as consumer spending, consumption of material goods, and energy intensity of those goods. Our results and suggestions for future expansion of the STIRPAT for marketing are then given.

1. Introduction

On March 8, 2014, Malaysia Airlines Flight 370 disappeared from air navigation radar with 239 passengers on board. The flight, heading to Kuala Lumpur from Beijing, took an unprecedented turn to the south; when it did, it entered the national spotlight as the world made a concerted effort to determine the plane's whereabouts (Innis, 2016). Although the aircraft was not found, what did become clear from the search was the large amount of trash in the world's oceans. Not only was the trash making the search efforts more difficult, but also the international news coverage kept showing search efforts within a large garbage patch in the Indian Ocean that was previously unknown because of its remote location. A garbage patch refers to parts of the ocean with a high density of human trash, primarily plastics, that weighs over 250,000 tons (Eriksen et al., 2014). Researchers have been studying trashing for a long time, but it was the crash of Malaysia Airlines 370 that first put the ocean's garbage patches in the international headlines (Mayer, 2014; Parker, 2014).

Although trashing and energy consumption have become more of a spotlight issue in recent years, energy usage is still at an all-time high and is expected to increase an additional 48% in the next twenty years (EIA, 2016). For instance, the amount of disposable plastic products researched, developed, marketed, transported, sold, and consumed continues to increase (Worldwatch Institute, 2016). It is estimated that eight million tons of plastic are placed in the oceans annually (Jambeck et al., 2015; Parker, 2015). Further, one of the largest contributors to the ocean garbage patches, disposable water bottles (Mayer, 2014), continues to rise in sales and are consumed at a rate 1.7 billion half-liter bottles a week in the United States (Fishman, 2016), of which at least 80% of will end up in the ocean (Schriever, 2013). Bottled water alone is also responsible for the release of over 2.5 million tons of CO_2 a year, which is the equivalent of filling each water bottle a quarter full of oil (Pacific Institute, 2007).

Additionally, despite the increased awareness of the devastating consequences of consumption (e.g., oceanic garbage patches, global warming, air pollution), it is difficult for marketing researchers to holistically quantify the consumer network contributing to the environmental damage. Instead, most research done in the field of marketing sustainability has been at a micro, single actor level, often referred to as "green marketing." This research is helpful, but incapable of demonstrating the dynamics between consumption actors. Therefore, we have been unable to pinpoint or rank the consumption actors that need to be targeted to slow or prevent further environmental destruction. Unfortunately, it is easy for each actor (e.g., researchers, producers, transporters, marketers, consumers) to pass the blame and/or responsibility for environmental destruction on to others.

Kilbourne and Beckmann (1998) found that there were three types of studies pertaining to marketing and the environment: green

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marketing, environmental policy, and environmental institutions. Each type of sustainability research varies in its scope. Green marketing started in the 1970s and examines how marketers address environmental concerns such as recycling (e.g., Bagozzi & Dabholkar, 1994; Zikmund & Stanton, 1971), pro-environmental commitment (e.g., Cho, Thyroff, Rapert, Park, & Lee, 2013; Ling-Yee, 1997), environmental beliefs (e.g., Kilbourne & Pickett, 2008) and pollution (e.g., Straughan & Roberts, 1999). These studies are also concerned about what makes a green consumer (e.g., Cho et al., 2013), why some consumers voluntarily simplify their lives (Cherrier, 2009, 2010), and how marketers can promote environmentally friendly products (Ginsberg & Bloom, 2004).

Environmental marketing begins broadening in scope as the policy implications surrounding sustainability are observed. Specifically, environmental policy examines the role of environmental claims, such as labeling or advertising, on society and the role that government can play in protecting critical entities. For instance, environmental policy includes conversations surrounding environmental labeling (e.g., Bickart & Ruth, 2012; Borin, Cerf, & Krishnan, 2011; Tang, Fryxell, & Chow, 2004), environmental taxation (Aasness & Larsen, 2003; Larsen, 2006) and legal standards in marketing (Gray-Lee, Scammon, & Mayer, 1994).

Most recently, the environmental literature in marketing has become even broader, as the institutions supporting environmental values are explored. This body of work takes a macro approach to studying the relationship between marketing, the natural environment and marketing systems (Mittelstaedt, Kilbourne, & Mittelstaedt, 2006; Press & Arnould, 2009; Prothero et al., 2011; Wooliscroft & Ganglmair-Wooliscroft, 2018). Frameworks such as institutional theory (Connelly, Ketchen, & Slater, 2010), stakeholder theory (Hult, 2011), and the dominant social paradigm (DSP) (Kilbourne, 2004; Kilbourne, Beckmann, & Thelen, 2002) are used to explore how prevailing institutions perpetuate continuous growth. However, despite the development of conceptual frameworks, there has been very little empirical work due to the difficulty of quantifying sustainability on such a macro-level (Kilbourne & Thyroff, 2016).

This is the approach we propose here. It is the institutions that perpetuate growth that must be examined, and, while Kilbourne and Beckmann (1998) provided a theoretical explanation of this approach, they offered no empirical support justifying change beyond mere dematerialization (within the prevailing paradigm) and generally reduced consumption (contradicting the existing paradigm). We need to draw a distinction between reduced consumption and dematerialization as they are not synonymous. While reduced consumption results in reduced material throughput by default, dematerialization need not reduce material throughput and can in fact, under some circumstances, lead to greater throughput. The crux of the issue as we perceive it is the difference between doing less (reduced consumption) and doing more with less (dematerialization). Therefore, this research quantitatively demonstrates the overall impact of the consumption of material goods broken down into various levels of marketing activities. While Waggoner and Ausubel (2002) provided the framework that guides this research, theirs was not a definitive study of the effect of consumption, but only an approach which we adopt in this research.

It is clear, for example, that population, as an element of the IPAT formulation, is a critical factor in ecological measures; it is the nature of its impact and how it materializes that is of critical policy importance. What this research demonstrates is that greening production (dematerialization) is a necessary but insufficient approach to long-term sustainability. It results in the expression of "getting worse off at a slower rate." The differences in policy implications when considering dematerialization (greening) the focus of previous research versus reducing consumption (sustainability) serving as the focus of this research are stark and can be considered to be nothing less than transformational. It is the difference between changing methods and changing paradigms.

To summarize the previous work done in marketing sustainability, McDonagh and Prothero (2014) suggested that marketing continue to move away from sustainability with a small micro-marketing, "s," to macro-level critical sustainability with a big "S." However, for this to happen, marketers must develop research techniques that can be used to test the exact environmental impact of consumption. Therefore, we suggest that marketing scholars begin to expand the STIRPAT model for marketing. By doing so, driving forces of consumption can be examined simultaneously so that their combined and individual impacts on the environment can be measured.

By applying the STIRPAT model in the field of marketing, researchers can examine sustainability at a tangible, macro-level, as consumption undoubtedly has a global impact. Further, consumption actors can be ranked on their environmental impact, which will provide stronger policy and managerial implications within marketing research. Therefore, the purpose of this research is threefold. First, we will introduce the STIRPAT model to the marketing industry. Second, we will begin to expand the STIRPAT model for use in consumer research. By doing so, we determine dynamic actor contributions to environmental impact within marketing. Third, we will give suggestions for future expansion of the STIRPAT model within marketing.

2. IPAT/STIRPAT

The STIRPAT model is derived from the IPAT model, which was developed around discussions taking place in the 1970s about the impact of population on the environment (e.g., Ehrlich & Holdren, 1971). The IPAT (I = PAT) model is a multiplicative approach to assess the role of population (P), affluence (A), and technology (T), on environmental impacts (I). Specifically, affluence is defined as GDP per capita, and technology as environmental impact per unit of GDP produced. Therefore, the IPAT model is identified as:

$$I = P \times GDP/P \times I/GDP$$

All of the variables are treated proportionally in the original IPAT. Further, due to the way in which affluence and technology are defined in the IPAT model, it is not an equation, but rather an identity. Therefore, by definition, the IPAT model is always true. However, the IPAT is still useful in formulating the relationship between environmental impact and its contributors (or driving forces) and in applications to determine which driving forces are most damaging to the environment (Harrison, 1993; Raskin, 1995). The IPAT model is also used to show how the environmental impacts from increases in one force can be balanced out with improvements in the others (Chertow, 2000). This entails a series of "what if" questions, one of which would be, "If population and affluence continue to increase at their current rates, how much would technology have to improve to keep the environmental impact at current levels?"

The IPAT model was extended into the STIRPAT model to allow for a practical, solvable equation (York, Rosa, & Dietz, 2003b). The STIRPAT model is the IPAT model in its stochastic form: the stochastic (ST) estimation of impacts (I) by regression (R) on population (P), affluence (A) and technology (T) on environmental impacts (I). The STIRPAT model is formulated as:

$$I_i = a\, P_i^b\, A_i^c\, T_i^d\, r_i$$

where a is the constant term, b, c, and d are exponents of the driving forces, and r is the residual for each observation. Affluence is still measured by using GDP per capita. However, technology is measured indirectly through the residual (York, Rosa, & Dietz, 2003a) as there is no consensus on a single measure of technology (Chertow, 2000). There are several dependent variables that have been used for measuring environmental impact. Two of the more common dependent variables are carbon dioxide emissions (CO_2 emissions) and ecological footprint (EF) as defined by the Global Footprint Network (2016). For this study, we have chosen the Ecological Footprint as the dependent variable. The definition provided by the GFN (2016, p. 1) is, "the Ecological Footprint measures the ecological assets that a given population requires to produce the natural resources it consumes (including plant-based food and fiber products, livestock and fish products, timber and other forest products, space for urban infrastructure) and to absorb its waste, especially carbon emissions." The measurement is provided in hectares required to maintain current ecological flows.

In the IPAT model, all of the parameters would be treated as equal (i.e., a = b = c = d = e = 1). However, in its multiplicative form, the STIRPAT model is difficult to solve. Therefore, the equation is converted into its log-log form by taking the natural log of both sides. Then OLS regression on the logged variables provides parameter estimates that are interpreted as the ecological elasticity (EE_{if}) of each driving force measured. The natural log is helpful as it converts non-linear variables to linear ones, rendering the results more susceptible to interpretation as percentage changes. The resulting log-log stochastic model is formulated as:

$$\ln(I_i) = \ln(a) + b[\ln(P)] + c[\ln(A)] + \ln(r_i)$$

As seen in the equation, both sides of the STIRPAT model are in natural logarithmic form, but b and c are now EE_{ip} (population elasticity) and EE_{ia} (affluence elasticity). Therefore, STIRPAT is ultimately measuring ecological elasticity of the forces in the equation much like price elasticity of demand is measured in economics.

Ecological elasticity is defined as the "responsiveness or sensitivity of environmental impact to a change in any of the driving forces" (York et al., 2003b, p. 354). The driving forces in STIRPAT are mainly population and affluence. Therefore, the ecological impact for population (EE_{IP}) is the percentage change in environmental impact resulting from a one percent change in population. Further, the ecological elasticity of affluence (EE_{IA}) is the percentage change in environmental impact resulting from a one percent change in affluence.

The same elasticity logic can be applied to the STIRPAT model as a whole, where coefficient elasticities (b and c) indicate the percentage change in I for every 1 percent change in P and A, with everything else held constant. Therefore, if b and c are equal to 1, then there is a positive proportional relationship between environmental impact and P and A. That is, the relationships between environmental impact and P and A are unitary elastic. However, when the coefficients are greater than 1, the environmental impact is increasing more rapidly than P and A indicating an elastic relationship. In contrast, when the environmental impact is less than one (but not negative), the relationship between environmental impact and P and A is considered inelastic, indicating that environmental impact is less responsive to changes in P and A.

Coefficients may also be interpreted when they are negative. When the coefficients are exactly −1.0, unitary negative elasticity exists. This indicates that environmental impact proportionally decreases for every percentage increase in P and A. Coefficients less than −1.0 are indicative of negative elasticity in which environmental impact is decreasing more rapidly than are P and A. If the coefficients are greater than −1.0 (but not positive), it indicates negative inelasticity in which a decrease in environmental impact is less responsive to a positive increase in P and A.

The IPAT/STIRPAT was originally used in the natural sciences, including biology and physics. However, since its development, it has been used in many additional fields, including ecological economics, forestry, sociology, engineering, and finance. It has been suggested that the STIRPAT research model be used in marketing studies, but that has not yet been implemented (Kilbourne & Thyroff, 2016). Therefore, in the next section, we will describe how STIRPAT can be applied to better understand consumption's impact on the environment within marketing. STIRPAT can also be used in other dimensions of the ecological problem including, but not limited to, regions rather than countries (e.g., rural versus urban), political orientations of countries, economic growth rates, States within countries, and multiple other dimensions. As the ecological footprint statistics continue to expand, other avenues of research will open.

3. Expanding STIRPAT for marketing

Waggoner and Ausubel (2002) began the expansion of the IPAT identity to render it more useful in sustainability research. Their work was important in two ways. The first was that they recognized the generality of affluence as a force and disaggregated it into two variables, the original affluence (GDP/POP) and a second variable they referred to as intensity of use, which was defined as Energy/GDP. In other words, they included the energy intensity of each unit of GDP. They renamed their model ImPACT, in which C is energy intensity of consumption. They also added a specific technology variable they referred to as efficiency that was defined as Emissions/Energy. Therefore, their model (ImPACT) was more detailed than the original STIRPAT model.

Waggoner and Ausubel (2002) also provided an initial approach that facilitates policy formation and monitoring in that it assigns responsibility for each of the dimensions in the model. Thus, not only did it specify more dimensions, but it also determined which segment of industrial society might be held accountable for them. These are the relevant levers for reducing environmental impact on a global basis. They also argued that their approach should be expanded so that more definitions, levers, and dimensions can be added to IPAT to facilitate a better understanding of the environmental impact of human behavior. These dimensions and levers will be discussed more thoroughly during the development of the model in this study.

Wei (2011) suggested numerous uses of the STIRPAT equation, reiterating that the coefficients in the model are ecological elasticities (EE) and are interpreted as the marginal environmental impacts of the driving forces represented in the model. It is through the elasticities of the driving forces that more enlightened policies for environmental amelioration can be developed. Essentially, they will not be the product of individuals' preconceived notions about the effect of the driving forces, and they will be based on the best available data regarding human-mediated effects on the global ecology.

3.1. STIRPAT in marketing

There are two main benefits of applying the STIRPAT model in marketing. First, sustainability in marketing research can continue to evolve by studying the micro level, "s" of sustainability, to the macro "S," as mentioned earlier. Up to this point, previous macromarketing sustainability literature has been conceptual (e.g., Kilbourne, McDonagh, & Prothero, 1997; Kilbourne, 1998, 2004) and the models have yet to be tested empirically. This limitation could be overcome by applying the STIRPAT model within marketing and consumption specifically. To do this, the original affluence and technology forces in the IPAT model can be expanded to include consumer choices and the ecological consequences of the choices.

Second, although there have been repeated calls to slow down economic growth (Costanza et al., 2014; Victor, 2010), levels of population and GDP per capita have continued to increase at about 2.5% per year (World Bank, 2016). The STIRPAT model can be used to identify the impact of different types and levels of consumption by quantifying their relative impacts on the ecological footprint. This would facilitate identifying specific factors that drive economic growth and reinforce the impetus to move away from the growth imperative driven by capitalism. Ecological economists have done this by applying the STIRPAT model yielding parameters for the two drivers, population and GDP/POP.

One difficulty here is that, as used previously, the STIRPAT variables of affluence and technology are too general to provide managerial and policy direction for marketing. Therefore, we suggest adding additional marketing variables. This can be done so long as the variables follow the same multiplicative logic as the original variables (York et al., 2003a). Ideally, this could be the analysis that changes the marketing ontology around sustainability as this too has been called for. Specifically, McDonagh and Prothero (2014, p. 1201) write, "we need research which fundamentally explores marketing's raison d'etre and considers how we change the consumption ideology (Kilbourne et al., 1997; Prothero & Fitchett, 2000)."

To do this, new drivers can be introduced that relate directly to consumer spending and specific measures of the ecological implications of the production of those goods. Thus, we are beginning to address the call by Waggoner and Ausubel (2002, p. 7861) for "the accretion of definitions and dimensions that IPAT has collected since it emerged." We also encourage the STIRPAT's future use and expansion within marketing in the future research section.

3.2. Driving forces expanded

In this section, we begin to expand the STIRPAT model to include marketing driving forces. We start with the basic STIRPAT model that contains only population (POP) and affluence (AFF) as driving forces and ecological footprint (EF) as the dependent variable. We can express the IPAT model as:

$$EF_i = a \times (POP)^b \times (AFF)^c \times r_i$$

Because the model is nonlinear as indicated earlier, we take the natural log of both sides and get:

$$\ln(EF_i) = \ln(a) + b\ \ln(POP) + c\ \ln(AFF) + \ln(r_i)$$

where the parameter a is the scale factor, b is the EE of population (EE_{IP}), c is the EE of AFF (EE_{IA}), and r_i is the residual for each observation. In the traditional STIRPAT model the residual is considered the effect of technology and other unexplained factors on EF. As such, this model represents a very general approach to the assessment of EF. To make the model more amenable to marketing research development, it needs to be further refined by decomposing both AFF and technology into more meaningful consumption related constructs. Consequently, we adopted Waggoner and Ausubel (2002) approach and expanded AFF into more consumption related ecological drivers. Schulze (2002) also used this approach to expand the IPAT model to include specific behaviors.

To expand the STIRPAT for marketing, we begin by keeping the dependent variable Ecological Footprint measured in global hectares (York et al., 2003b). For the independent variables, we start with population (POP), but then expand the rest of the model to include gross domestic product (GDP), consumer spending (CS), consumption of material goods (MG), energy intensity of consumption (EN), and CO_2 intensity of energy (CO_2). It was important to identify additional drivers that might affect ecological impact, while also maintaining the integrity of the STIRPAT approach by ensuring that the resulting expanded model maintains the required multiplicity of terms.

Again, we started by keeping POP, but then expand AFF. AFF in STIRPAT represents GDP per capita, but we add consumer spending, (CS/GDP), and the consumption of material goods, (MG/CS). This approach removes GDP related to industrial goods and separates material goods from services. The new equation for this model would appear as:

$$EF_i = a \times (POP)^b \times (GDP/POP)^c \times (CS/GDP)^d \times (MG/CS)^e \times r_i$$

As is, the model has two terms that have been added to measure the consumption of material goods. This leaves r_i as a catch-all term for the technological contribution of the consumption of material goods to the ecological footprint.

To further refine the model, we take two specific aspects of technology, namely energy intensity of consumption (EN/CS) and CO_2 intensity of energy (CO_2/EN), into consideration. We deconstructed r by providing two measures of technological impact of consumption yielding the testable log-log model:

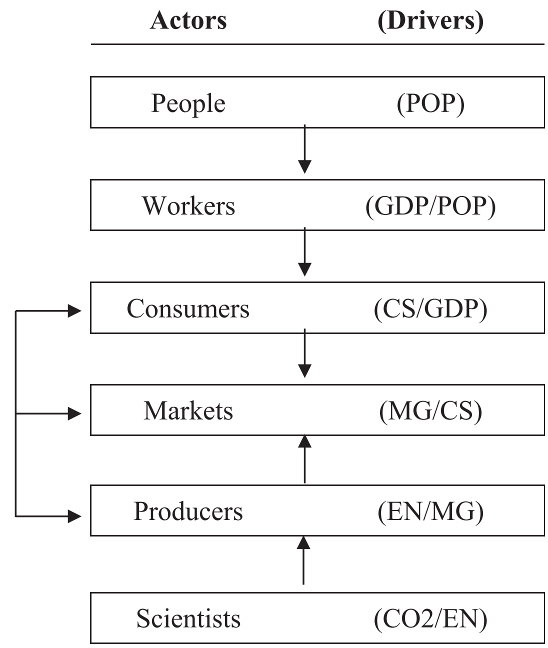

Fig. 1. Actor/Driver Map.

$$EF_i = a \times (POP)^b \times (GDP/POP)^c \times (CS/GDP)^d \times (MG/CS)^e \times (EN/MG)^f \times (CO2/EN)^g \times r_i$$

This deconstruction of the original IPAT model can provide information directly related to many of the consumer/producer related ecological policy drivers. The importance of each driver in the global ecological footprint is indicated by its EE_{ij} parameter estimate.

3.3. Actors and driving forces

For effective research instruments to be developed, there must be some indication of what they involve and to whom they should be directed. Therefore, in this section, we follow the lead of Waggoner and Ausubel (2002), who further refined their IPAT model and identified actors with each of the identified driving forces, as well as assigning an actor to each driving force. In this way, ecological policy initiatives can be better connected to the source of their contribution to EF. Fig. 1 provides the relationships between actors and drivers of the model. Specifically, people represent POP; workers represent GPD/POP; consumers represent CS/GDP; markets represent MG/CS; producers represent EN/MG; and scientists represent CO_2/EN.

There are certainly exceptions to the process, e.g., all people do not necessarily become workers everywhere in the world or in all segments of society. But this approach does parallel the circular flow model prevalent in economics to a reasonable degree, as will be indicated throughout.

3.3.1. People (POP)

While there is still some argument as to whether the population is a driver, with Simon's (1980) being the most frequently cited assertion, more recently, the discourse on population has been less contentious as to its role in the EF. The original position of Ehrlich and Holden (1971) has been well established in recent empirical studies such as Dietz and Rosa (1997). Specifically, most models indicate a large, almost proportional contribution with a 1% change in population making an almost 1% contribution to EF (see, for example, Liddle, 2011, 2015; Fan, Liu, Wu, & Wei, 2006; Dietz & Rosa, 1997). But when examining different levels of development across countries, this number can vary (Fan et al., 2006), being higher in more developed economies. The primary responsibility of the population driver is humans opting, for whatever reasons, to be parents, thus creating the household sector in the circular economy.

3.3.2. Workers (GDP/POP)

Waggoner and Ausubel (2002) argued that it is the number of people available to become workers that then drives GDP. This is analogous to the factor market in the circular economy model. The driver here becomes GDP/POP, the volume of goods and services produced by those employed as labor in the business sector of the model. The sale of one's labor through the labor market has two immediate effects that precipitate factors changing the EF. When individuals sell their labor, they increase GDP proportional to their productivity, and they can no longer produce for themselves. At this point in the model, GDP/POP is the driving force and the actors responsible are workers.

3.3.3. Consumers (CS/GDP)

As workers increase the supply of goods (GDP), Keynes' (1936) version of Say's Law (supply begets its own demand) would suggest that they simultaneously transform themselves into consumers who must satisfy their specific lifestyle needs in the market with the same products they collectively created as workers (Jonsson, 1995). And because the focus of this study is the consumer, we restrict the market to include only consumer purchases and exclude that part of GDP that is produced for industry. This requires the restriction of the worker's driver to include that part of GDP that is related to consumer spending or, the consumer's driver. This driver is defined as CS/GDP and provides the part of GDP that can be attributed to consumers as the responsible actors, as it is they who choose how much to spend and what to spend it on.

3.3.4. Markets (MG/CS)

Again, because the focus is the role of consumer spending in the EF, we further restrict consumer spending to include the part of consumption that contributes most to the EF. This is considered to be the production and consumption of material goods, sometimes referred to as the materialization of the economy, so we restrict consumer spending and exclude the consumption of services that have a much smaller impact (though not nil) on EF. Here, the restricted consumer driver relating to the material goods intensity of consumer spending is argued to be a function of the interaction of consumers and producers (reflected in their link in Fig. 1). The driver in the market process is then material goods/consumer spending. While there are many dimensions through which the market efficiency assumption may be discussed, they are not a part of this research.

The reason we place responsibility for this driver on the market is that the combination of goods and services output is determined by information flows between producers and consumers in that market. From the market driver, it can be seen that consumers provide spending and producers provide goods or services, while the market process determines the particular output ratio. While the market is an abstract entity, consumer policies can be implemented through the market as has already been demonstrated in such economic strategies as cap and trade mechanisms. But we still need a mechanism to join material goods consumption with the EF.

3.3.5. Producers (EN/MG)

One of the most frequently studied and most important contributors to the EF is global energy consumption (Wackernagel et al., 1999). Every physical process requires the consumption of energy of some kind, and the choice of the energy source is made by producers, based on short-run profitability, although there are certainly some exceptions to this. While there are many energy alternatives that greatly vary in their contribution to EF, fossil fuels are the most frequently used and the most damaging to the environment (Gössling, Hansson, Hörstmeier, & Saggel, 2002). One of the most important contributors to the EF is the level of carbon in the fuel burned for production, which currently constitutes 60% of the global EF (GFN, 2016). No other single factor is nearly that large, so we chose to use two measures in the study. First is the overall energy consumption used in the production of material goods. The measure is energy/material goods. The responsible actor at this level is the producer who makes energy choices in driving the production process. The central characteristic of the source of energy is its contribution to the accumulation of CO_2 in the atmosphere, which is determined by the type of energy used. Scientists are well aware of this factor and have been for years (GFN, 2016).

3.3.6. Scientists (CO_2/EN)

The World Bank (2016) measures CO_2 contribution in terms of the kilogram (kg) equivalent of a kg of oil. The equivalence is considered to be approximately 3 kg of CO_2 per kg of oil. This is a counterintuitive result on the surface, but occurs as a result of the chemical process in which each atom of carbon released from combustion of fossil fuels combines with two atoms of oxygen to create CO_2. Thus, the number of kg of CO_2 created exceeds the kg of oil used. How to decrease the quantity of CO_2 released in the atmosphere falls in the domain of science, so the responsible actors here are scientists. It is clear that not all scientists are actively involved in reducing CO_2 production, but those who are have the ability to make positive contributions to the environment. The problem here relates to the role of profit in capitalist-oriented organizations whose primary function is profit, which requires reducing energy costs; this goal may not be related to the reduction of CO_2 emissions. But for those organizations whose objective is to increase energy efficiency, there is the potential for impacting the CO_2 driver that we define as CO_2/EN.

3.3.7. Circular flow

We now turn to the importance of the market as the nexus through which all of these factors are integrated, which will bring us back to the role of consumption in the ecological process. In that process, the circular flow model of the economy can be seen in that consumers interact with producers in the product market, resulting in a particular set of goods being produced for those consumers. The driver, MG/CS, results from this interaction. How these goods are produced depends on the particular set of options the producer has in the factor market, and this choice creates the producer's driver, EN/MG. Tying this back to the EF indicates that if consumers in the product market demand more ecologically efficient products, then the producer revisits the factor market to secure more ecologically benign production capabilities through scientific development and technology that reduce CO_2/EN by changing its particular energy mix (EN/MG). As with the circular flow model, this process is continuously in flux with constantly changing parameters. This is why, for example, the biocapacity of the earth has increased slightly over the past two decades. Producers have incorporated scientific development into the production process, but not at a rate sufficient to offset increases in the EF. This is the condition that prompts the often-heard comment, "We are becoming ecologically worse off more slowly."

In the next section of the paper, we provide the methods and results of the analysis. In the last section, we develop several approaches to interpreting the results and then provide the strategic and public policy implications of the results, including examples of consumption and production policies that might be considered for reducing the growth in the EF. We also give a number of suggestions for future expansion of the STIRPAT for marketing.

4. Methodology

4.1. Analytical approach

Multiple regression is the approach chosen due to its standard usage for STIRPAT-type analyses; utilizing it is appropriate because all variables are continuous and meet the STIRPAT multiplicative requirement.

The results of the analysis can then be used to predict the consequences of changes in the driving forces, the independent variables, on the ecological footprint (EF), the dependent variable. This method was also chosen because reliable secondary data are available for all of the independent variables through the World Bank (2016), and the EF data were available through the Global Footprint Network (2016). The data were from the 2011 statistics, and all dollar measures were in 2011 USD. Data that were not directly available could be derived from the available data.

The model being developed is a static one which includes data for all countries at one point in time. Thus, the coefficients apply to one point in time, but they are somewhat stable over time. Thus, they are still useful in determining the effect of changes in the drivers over relatively short periods. Additionally, the EF can be estimated under different assumptions regarding changes in the drivers, some of which are predictable from past trends. This is also the approach taken in much of the work on ecological elasticities (see, for example, York et al., 2003a, 2003b; Liddle, 2011; Waggoner & Ausubel, 2002).

Specifically, three expanded equations are presented. The first equation specifies the expanded equation in the original IPAT multiplicative form. The second equation specifies the relationships between the drivers by taking the log of the first equation; it is the equation to be used in the log-log regression to estimate the parameters. The third equation contains the estimated parameters in the traditional STIRPAT log-log format.

4.2. Data

Data for the driving forces that are correlated with the EF were obtained from the 2011 world development indicators of the World Bank. The year 2011 was chosen as it was the last year for which EF data were available for most of the countries in the World Bank database. Only countries for which all necessary data were available were included in the sample. The sample started with 188 countries, but after filtering the set for data availability, the final completed sample contained 113 countries that contained approximately 90% of the world population. In these countries, the data for the analysis of the model were either directly available or could be computed from data that were directly available. For example, population was directly available, but GDP was given in GDP per capita. We obtained measures of GDP by multiplying GDP per capita by population for each country. No data were interpolated or imputed.

The data set included measures of population (POP), GDP, consumer spending (CS), consumer spending on material goods (MG), energy consumption (metric tons of oil equivalent) (EN), and carbon emissions (in metric tons) (CO_2). These variables allowed for the computation of all the EF drivers in the proposed model (in Fig. 1).

4.3. Analysis

The original nonlinear model with all of the drivers is specified as:

$$EF_i = b_0 \times (POP)^{b1} \times (GDP/POP)^{b2} \times (CS/GDP)^{b3} \times (MG/CS)^{b4} \times (EN/MG)^{b5} \times (CO2/EN)^{b6} \times r_i$$

where the dependent variable is the ecological footprint (EF); b_0 is a scale factor; b_1-b_6 are the exponents for the drivers; POP through CO_2/EN are the drivers specified in Fig. 1; and r_i is the residual for each country. To compute the elasticities, this model was reconstituted as a log-log regression model that can be calculated using standard regression techniques. The model tested is specified as:

$$\ln(EF_i) = b_0 + b_1 \times \ln(POP) + b_2 \times \ln(GDP/POP) + b_3 \times \ln(CS/GDP) + b_4 \times \ln(MG/CS) + b_5 \times \ln(EN/MG) + b_6 \times \ln(CO2/EN) + r_i$$

After the analysis, the estimated coefficients, b_j, provide the ecological elasticity for each of the drivers, r_i is the residual for each country, and b_0 is the intercept. To return to the original multiplicative model, b_0 and r_i, must be exponentiated, but this transformation is not necessary for interpreting the result as a log-log regression.

4.4. Hypotheses

Here, we briefly propose a few hypotheses based on the theory and methods mentioned earlier. We will present the findings of these hypotheses in the following results section. For our first hypotheses, we predict that the ecological footprint for the overall model is expected to be significant. Therefore, for our first hypotheses we predict:

$H1_o$: $\beta_k = 0$ (k = 1…7)
$H1_a$: $\beta_k \neq 0$

Specifically, this hypothesis states that the model proposed will be a significant predictor of ecological footprint overall, with the null hypothesis predicting the opposite.

Second, we test for significance of our independent variables of people (POP), workers (GDP/POP), consumers (CS/GDP), markets (MG/CS), producers (EN/MG) and scientists (CO_2/EN). Specifically, we test that one or more coefficients (independent variables) are significant. Therefore, we hypothesize:

$H2_{o:}$ $\beta_0 = \beta_1 = \beta_2 = \beta_3 = \beta_4 = \beta_5 = \beta_6$
$H2_a$: $\beta_i \neq \beta_j$ for some $i \neq j$

This hypothesis states that one or more of the β coefficients will be significant in predicting ecological footprint. It does not require that all coefficients be significant though, as we are not predicting that this will be the case.

5. Results

The OLS regression results are presented in Table 1. As can be seen in the table, the model with a full set of consumer-related drivers is significant and explains 97.70% of the cross-national variance in EF. Therefore, H1, which predicts that the overall model will be significant in predicting EF, is supported. The VIF of each driver was also determined as the requirement to maintain the multiplicative structure of the original model results in several driving forces that might cause collinearity. While there is no clear maximum for VIF, the consensus is that it is 10 (Chatterjee, Hadi, & Price, 2000). Our results indicate that the highest VIF of any variable in the model was 6.23, which is within these guidelines. Thus, the model and each of its driving forces is a good predictor of EF overall. We now examine the individual terms.

It can be seen that all of the drivers except CO_2/EN are statistically significant and positive. Therefore, H2, which predicts that one or more of the drivers in the model will be significant, is also supported. Further, all the significant coefficients are between zero and one, indicating that the drivers are at various levels of inelasticity. This indicates that

Table 1
Log-Log Regression Results.

Ecological Drivers	Log-Log Coefficients Equ. 3	P-values Equ. 3
CONSTANT	−0.20	0.611
POP	0.95	0.001
GDP/POP	0.58	0.001
CS/GDP	0.70	0.001
MG/CS	0.43	0.001
EN/MG	0.36	0.001
CO_2/EN	0.00	0.961
R^2	0.98	

increases in the value of the driver result in less than proportional increases in the EF. This also reveals that the original formulation of the IPAT equation assuming proportionality is not valuable as a predictor. It is clear that the most significant driver, as is the case in many STIRPAT analyses, is population, the coefficient of which is 0.949, indicating a nearly proportional contribution to EF. All other drivers contribute less than proportionally and positively to EF.

To be consistent with previous STIRPAT research, we present the log-log equation of our results as:

$$\ln(EF_i) = -.198 + .949 \times \ln(POP) + .582 \times \ln(GDP/POP) + .697 \times \ln(CS/GDP) + .427 \times \ln(MG/CS) + .360 \times \ln(EN/MG) - .002 \times \ln(CO2/EN)$$

The results and their respective p-values can be found in Table 1. We now turn to a discussion of the results and their importance to both marketing strategy and policymakers. We then provide future research suggestions that offer many avenues for future expansion of the STIRPAT within marketing.

6. Discussion

One of the longest standing propositions regarding ecological degradation is that, based on current resource estimates and growth rates, increasing populations worldwide cannot be supported. In 1976, the ecological capacity (biocapacity) of the Earth was thought to have been surpassed, indicating that we were using resources faster than they can be replaced. The basic argument is that we are now living on nature's capital rather than its income. The more people (consumers) there are, the more quickly the growing ecological footprint will exhaust the biocapacity of the Earth. But how much time do we have before the damage caused by increasing consumption becomes irreversible?

The equations developed using the expanded STIRPAT equation for marketing allow us to start making educated guesses about such questions. Specifically, the log-log tells us the effect that a 1% increase in population will have on the EF while holding the other drivers constant. Based on the parameter values derived from the log-log regression, the coefficient of POP is 0.95, indicating that for every 1% increase in population, the EF increases by 0.95%.

GDP per capita has an elasticity of 0.582. This indicates that as the GDP increases by 1%, the EF goes up by 0.582%. The caveat here is that the model upon which the analysis is based is the circular flow economy, within which GDP is produced by people who become workers and who are then transformed into consumers who consume the production. So while the drivers are considered independently, as the circular flow model of the economy suggests, they are not logically independent. The model suggests that if one could hold everything else constant, this is the result that would ensue, but the circular flow model of the economy tells us that all other factors cannot be held constant as GDP increases. This must be kept in mind as the model is used for strategy and policy purposes.

Drivers CS, MG, EN, and CO_2 can be assessed just as POP and GDP were, but CO_2 requires some explanation. The regression coefficient for this driver was based on the ratio CO_2/EN, the only one that was not significant. Because CO_2 has been described as one of the most important drivers of expanding EF with worldwide attention, it is somewhat anomalous that it is not a significant driver in the model. The explanation for this relates to the fact that scientific development in reducing CO_2 emissions progresses slowly, and the same technologies (with minor variations) are used in production systems in most countries. As a result, there is little variation in this driver at a single point in time because the ratio of CO_2 to energy is constant with a weighted average (based on the quality of fossil fuels used) of about 3:1. So, while there is no variation in the data for this driver, it is still one of the most important measures in the EF.

Finally, the model allows for the simultaneous testing the consequences of changes in all drivers. This result can be assessed within the log–log model as the sum of the coefficients for the drivers times the percentage change. We could easily determine, for example, the overall effect on EF for a 2% reduction in the drivers simultaneously. However, a change of 2% in all the drivers is wholly unrealistic. Rather, the projections that will be provided shortly are based on the percentage change in the rate of growth of the drivers, not the drivers themselves. In this scenario, the ideal would be to achieve a 100% reduction in growth among the drivers. This would result in a stable state or a no-growth society. The value of this information in policy formation and assessment lies in the ability to project the consequences of changes in the drivers over time. While it may be argued that we already know that population increases cause environmental damage, the contribution of this research is that we can now estimate the amount of damage and prioritize policy development. We can estimate very closely, for example, the current growth rates in all the drivers and then determine the effect of reducing the growth rates on the EF in a future time period of perhaps 20 or more years.

Thus, using all the data that are currently available on each of the drivers, we find that the annual growth rate for each of the drivers is population 1.1%, GDP 2.5%, consumer spending 2.4%, consumer goods 2%, energy consumption 2%, and CO_2 emissions 2.6%. Plugging these growth rates into the model shows that the annual growth in EF is approximately 1.62% per year. Clearly, the number of years to use in computing the growth rate for each of the variables is arbitrary, and some may use all data as we did here, or they may choose to use data only from more recent years. Either method would provide information for both marketing strategy and policymakers on the longer-term effect of current trends. In this estimate, the twenty-year effect would be an increase of approximately 5 billion hectares of EF for this sample of countries. The estimated 2011 biocapacity for this sample of countries is approximately 11.1 billion hectares, and the estimated EF is 13.3 billion hectares indicating that the EF already exceeds biocapacity and the shortfall is increasing. If this increase is unacceptable to firms or policymakers, the model provides information about which drivers could be reduced to get the best return and to whom the strategy or policy should be directed. It was our intention to consider population, energy, and affluence as the three main pillars of the ecological problem. This was the motivation for beginning with the I = PAT framework in the first place. Our central pillar remains that it is the interaction of these factors that creates the framework for policy. Any policy instruments that do not consider the interaction of P, A, an T are doomed to fail in the long term.

7. Future research: suggestions for expansion

So far, we have addressed the first two purposes of this research. First, we introduced the STIRPAT to marketing and second, we began to expand the STIRPAT model for an understanding of consumer research. However, perhaps the key to this research lies in its potential and future applications. In this section, we address the third purpose of providing suggestions for future expansion of the STIRPAT in the field of marketing. Specifically, we provide suggestions for the STIRPAT's expansion in the areas of services, material, industry and product categories, renewable energy, longitudinal data, marketing education, and additional cultures. However, we hope marketing researchers will go beyond these suggestions, as these are not comprehensive.

7.1. Services

In this manuscript, we expand the STIRPAT for marketing by including population, gross domestic product, consumer spending, consumption of material goods, energy intensity of consumption and CO_2 intensity of energy. However, as it stands, we do not distinguish between material goods and the service economy. Future research should continue to expand the STIRPAT to account for both types of spending, as service is a significant part of the world GDP and the service economy is seen as an increasingly important trend within marketing. Future research should consider ways to incorporate services such as air travel, car travel, hospitality, tourism, financial services, and other services into the STIRPAT equation.

7.2. Material, industry and product categories

The current expansion of the STIRPAT does not distinguish between different types of raw materials or different product categories. Therefore, in the future, we also recommend an expansion of the STIRPAT that differentiates the energy usages surrounding different materials (e.g., crude oil, cotton, coal, plastics, iron, wood). For instance, following the Vietnam war, Vietnam has been careful to grow their GDP, but not at the expense of deforestation (Tatarski & Johnson, 2016). Understanding the role of raw materials can help us better grasp the impact that the lessening of deforestation has on EF and on potential spillover effects onto other raw materials. It would also be helpful to expand the STIRPAT to distinguish between different types of industries (e.g., construction, education, aerospace, entertainment, electronics, pharmaceutics, hospitality, health care, transportation, computing), as well as between different product categories. Business-to-business classification may also be worth considering in future expansions.

7.3. Renewable energy

Forms of energy that do not deplete and can be replenished in a human's lifetime are referred to as renewable energy. Examples of renewable energies include wind, solar, hydropower, geothermal and biomass. Interest in renewable energy has taken off in recent years as innovations have made the harnessing of renewable energy more effective, efficient and affordable (Dudley, 2018). Future research on the STIRPAT should consider expanding the model to add renewable energy to the equation. For example, by ramping up their investment in several renewable sources such as energy storage, solar, and wind energy, over 50% of the energy usage in Sweden is renewable energy – and they aim to have that number to 100% by 2040 (Sweden.se, 2019). Similarly, New Zealand is up to using 40% renewable energy (EECA, 2016). Adding renewable energy to the STIRPAT equation can allow researchers to understand the impact that it has on EF as well as the other marketing variables in the equation.

7.4. Longitudinal

Another limitation of the current study is the data used in estimating the parameters were from a single year - making the model static. Thus, projecting to future time periods can be problematic as is frequently the case in economic projections. The model is, as are all models, a simplification of the reality underlying the ecological footprint. This is also a caveat in interpreting the results. Therefore, in the future, more complex approaches to modeling should be undertaken. This includes incorporating longitudinal estimates for parameters. Additionally, researchers should consider time series, where the t (error) is converted into time series equations with an extended dataset.

7.5. Marketing education

The STIRPAT may also help educate marketing and business students on the macro effects of marketing on the ecological footprint. Therefore, future research should also discover, implement and study different ways in which STIRPAT may be incorporated successfully into classroom learning. Activities could include, but not be limited to, the application, expansion, and scenario "what-ifs" of the STIRPAT by students. Another approach for future research would be classroom simulations using the STIRPAT – whereby different scenarios may be determined and the long-term effects of many policy approaches can be studied.

7.6. Additional cultures

Data from a global sample of 113 countries were utilized in this research. Estimation of the elasticities of subsets of the countries, such as affluent countries or countries with different political and economic orders, might be useful in developing policies in diverse countries. Therefore, future research may also consider including country typologies as a variable in the model. It may also be beneficial to control for age groups and social class within countries. We are hopeful that other researchers will incorporate STIRPAT-like approaches in future studies of consumption and marketing research.

8. Conclusion

The initial purposes of this research were to first introduce and then expand the STIRPAT model into marketing so that a research tool exists to simultaneously study the environmental impact of multiple actors. Therefore, we introduced the concept of IPAT and STIRPAT. Then, beginning with the basic IPAT identity, methods developed in sociology and ecological economics were expanded to make them compatible with the consumer framework. This approach is not only useful in identifying the relevant ecological drivers, but in prioritizing them as well. Waggoner and Ausubel (2002) argued that there is an additional contribution to policy-making in this approach, i.e., identifying different segments of society that maintain some responsibility for each of the drivers in the change in global EF. This allows for policy or strategy to be designed and directed at specific actors affecting changes in the EF.

The model in Fig. 1 was loosely developed based on the circular flow model used in standard macroeconomics that explains how consumers, producers, product markets, and factor markets interact to create economic flows. Fig. 1 parallels this process, providing both the ecological drivers and the actors who can be argued to be responsible for increases and decreases in the drivers. The model flows such that the population provides workers (factor market) who sell their labor to businesses and produce the GDP for a nation, or in this case, the world. As the GDP is produced by workers, they recreate themselves as consumers who enter relations with business in the market for goods. Market equilibrium is achieved when the market for goods clears, and the process continues indefinitely. If consumers demand a different type or quality of good (in this case, less ecologically damaging), business must go back to the factor marketing, seeking a way to produce the ecologically improved goods by securing the services of scientists who can improve the ecological costs of the goods available.

This process is carried out through the behavior of various actors who can change the process if they choose. Population, for example, is the choice of people to reproduce, creating more population (POP). As adults, most members of the new population must work and, in so doing, increase the GDP by their number and productivity. That is GDP per capita, and it creates their driver, GDP/POP. Consumers then enter the market to buy a percentage of these products (consumer spending) that relate to their needs, creating their driver, CS/GDP. The mix of goods and services is determined by market mechanisms that yield the volume of material goods (MG) and thus, the driver for the market, MG/CS. Market mechanisms inform businesses on how to produce the goods by allocating the right resources, one of which is the type and amount of energy used in the production of the goods. This creates the producer's driver, which is the amount of energy used in producing the volume of goods necessary. This creates their driver, EN/MG. Finally, when called for, scientists try to increase the efficiency of different types of energy in terms of the production of greenhouse gasses such as CO_2. Their driver then becomes CO_2/EN.

These drivers were combined in a multiplicative model similar to

Table 2
Twenty-Year Projections of EF Based on Policy Success.

% decrease in growth	Pop	Gdp	Cons	Goods	Energy	CO_2	Annual change in EF	20 Yr change in EF
0%	1.231	1.599	1.569	1.457	1.457	1.671	0.0162	1.3777
10%	1.206	1.526	1.501	1.403	1.403	1.552	0.0145	1.3347
20%	1.181	1.457	1.435	1.352	1.352	1.479	0.0129	1.2927
30%	1.157	1.390	1.372	1.302	1.302	1.409	0.0113	1.2522
50%	1.110	1.266	1.254	1.208	1.208	1.278	0.0081	1.1746
75%	1.054	1.126	1.120	1.099	1.099	1.131	0.0040	1.0831

I = PAT, but modified to represent an equation rather than an identity. The drivers were then transformed to yield a log–log regression model through which the coefficients that represent the ecological elasticities for each of the drivers were computed, wherein the dependent variable was ecological footprint (EF). Table 2 provides a brief example of how the elasticities might be used to determine longer-term effects based on projected success rates for individual policies directed at the ecological drivers. The table begins with the twenty-year change in EF based on current growth rates for each of the drivers. It then reduces each of the growth rates by various decrements. The results indicate that under current growth rates, the EF will increase by 38% in the next 20 years. But if marketers and/or policymakers are successful in achieving a 10% reduction in the growth rates of all drivers, the growth in EF after 20 years is 33%, or a net reduction of 5% on the EF.

In interpreting the resulting equations for social implications, it is important to look at both the overall ecological consequences of the model and the effect of each of the drivers separately to focus policy and marketing strategy development where the greatest gains can be made the quickest. Further, as shown in Fig. 1, each driver has an actor whose behavior has the greatest impact on that driver. From the computed model, it can be seen that the two largest drivers are population (0.95) and consumer spending (0.70), with GDP/capita (0.58) close behind.

As such, the strategic implications of this research are that marketers should focus first on consumer spending and energy use as these are the largest drivers. While population growth is the largest drive, that is strictly a policy directive as marketers have no direct control over it. It also indicates that drivers should be directed at adults because they have the greatest effect on population growth and consumer spending. The major caveat in this analysis is that producers and consumers must recognize and accept the implications of continued unbridled economic growth. This would determine their willingness to make hard choices as to what and how much to produce and what and how much to consume.

The importance of population and energy comes as no surprise as these have been the source of much discussion for more than 30 years now. The empirical approach taken here confirms that this attention was not misdirected, and more importantly, that the effect of the drivers has not been abated over recent decades. Population growth, consumer spending, and energy consumption are still primary drivers of the increase of the EF worldwide. Policy initiatives to slow global population growth have been attempted with varying degrees of success over the past five decades and are not the focus of this paper. It suffices to say that technological solutions such as birth control have been relatively unsuccessful; in fact, it has become abundantly clear that technological solutions to cultural change are generally deficient (Winner, 1986). Effective policies must be developed more holistically, with substantial regional variations taking in more recent knowledge related to science, technology, and society.

This research method also allows us to quantify the large impact that consumer spending has on EF. While Kilbourne and Beckmann (1998) showed that the study of green consumers has had a long history, and McDonagh and Prothero (2014) confirmed that it is still true, there has been no systematic study of the ecological consequences of consumption and its role in sustainability within the marketing discipline. While the last 30 years have seen a dramatic increase in the study of consumption behaviors, particularly regarding the pernicious effects of materialism on individuals, its role in sustainability has been approached from a conceptual basis rather than an empirical one. On the basis of the model developed here, we can see the effect of consumer spending on the EF. Because of that, sustainability is important and should become a target for consumer policy and strategy development.

For instance, based on our results, if consumer spending as a percent of GDP was reduced by 1% as a result of the strategy changes, the EF would go down by $(0.99)^{70}$ or 0.7% per year. This assessment refers to a change in the driver itself rather than the rate of growth of the driver as above. If this were encouraged on a strategy or policy level, over a twenty-year period, the change would amount to a 15% decrease in the EF. It is clear that such a strategy or policy would influence consumers directly, producers indirectly, and be played out through the market. The value of the STIRPAT approach to policy becomes evident in the fact that the effect of the policy can be determined and balanced against the cost which, in this case, Hansen (2009) argued is almost nil.

The third driver that is critical according to our results is energy consumption as a percent of material goods (the energy intensity of material goods), the coefficient of which is 0.36. The primary actor in this driver is the producer who decides on energy sources for production, most often on the basis of least cost. As a result, carbon-based fossil fuels (particularly coal) are the main sources of energy. Policies in this domain have been attempted in various forms of “cap and trade” devices, but these have been very ineffective, and Hansen (2009) argued that they will continue to be. Rather, policies and strategies that play out effectively in the market are desirable.

For example, by adding high carbon taxes to products that require carbon intense energy sources, the cost of those products will go up, and when the increases are added to the market price, the producer will be at a competitive disadvantage over those who shift to lower carbon intense energy sources. The higher the tax imposed, the greater the disadvantage and the greater the motivation to shift to a business strategy that uses more efficient energy sources. As the circular model of the economy suggests, this would motivate producers to go back to the factor market for scientific input in how to become less carbon intense. Those who succeed in shifting the quickest will be the ones who regain a competitive advantage.

When successful, this approach will result in decreases in carbon output and, thereby, decreases in the EF. In this instance, the reduction in the EF for a 1% reduction in energy per unit of material goods would be $(0.99)^{36}$ or 0.36% per year. This would be a net reduction in the EF of 7.45% over a twenty-year period. In both the consumption and production conditions, the tax would be predicated on estimates of the price elasticity of demand for the products in question, and this might require some trial and error approaches to arrive at the tax rate that would achieve the desired results. But this can be achieved with support from both government policymakers and consumers. The beauty of this approach is that it is both simple, and more importantly, falls within the market paradigm that underlies all Western industrial societies. That is, it works within the competitive market system with few changes. To use policy in a more intrusive way would be far more difficult, but not impossible. It would represent generational changes rather than quick fixes within the market context.

The more dramatic socio-economic changes would be at the paradigm level and would challenge the prevailing system itself. This falls into the political context of radical versus reform politics. If one assumes that the ecological problem is amenable to market reform such as that proposed above by Hansen, then market failures can be remedied by transforming prices to reflect full ecological cost. If one assumes the problem lies in the failure of markets to exist, then the challenge is much more complex and may not be remediated by appropriate pricing.

This falls in the area of radical political change because it assumes that the system is the problem. Policy implications, in this case, must be more radical and transformational, as in Giddens' The Third Way (1998). A discussion of this approach lies well beyond the scope of this research.

In sum, this research method allows populations, workers, consumers, markets, producers and scientists to all see their role in the impact of the carbon footprint. Although the results may seem obvious to those reading or studying this research, it is clear that those who are responsible for the drivers often have a hard time understanding how they are impacting the planet. In a world where the population is larger than the world can sustain, it is important to quantify the impact of the other drivers, so that the actors can play their parts in achieving a healthier, more sustainable EF.

However, it is important to note a limitation of our approach. The proposed model is predicated on the circular flow model of the economy, indicating that drivers should not be assumed to be constant when other drivers change as is done in regression models. In this model, for example, one should not assume that consumer spending can vary while GDP is held constant because they are not logically independent in economic reality. Doing so could lead to some anomalous conclusions. Thus, consideration must always be given to the political economy regime in effect.

This research also offers many avenues for future expansion of the STIRPAT model. This research should be seen as an introduction to the STIRPAT for marketers as well as the beginning of the expansion of the STIRPAT model for those marketers. However, much work can still be done to make the STIRPAT even more valuable to marketers, businesses and policymakers. Therefore, we encourage the expansion of the STIRPAT into the areas of services, material, industry and product categories, renewable energy, longitudinal data, marketing education, and additional cultures, all with the hope that marketers will go beyond these suggestions as well.

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