Impure Public Goods and the Comparative Statics of Environmentally Friendly Consumption

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Abstract

This paper develops an impure public good model to analyze the comparative statics of environmentally friendly consumption. "Green" products are treated as impure public goods that arise through joint production of a private characteristic and an environmental public characteristic. The model is distinct from existing impure public good models because it considers the availability of substitutes. Specifically, the model accounts for the way that the jointly produced characteristics of a green product may be available separately as well—through a conventional-good substitute, direct donations to improve environmental quality, or both. The analysis provides a theoretical foundation for understanding how demand for green products and demand for environmental quality depend on market prices, green-production technologies, and ambient environmental quality. The comparative static results generate new insights into the important and sometimes counterintuitive relationship between demand for green products and demand for environmental quality.

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1 Introduction

Consumers are often willing to pay for goods and services that are considered "environmentally friendly" (or "green"), and markets designed to meet this demand are expanding. Market research in the United States has found that green products account for 9.5 percent of all new-product introductions in the economy (Ottman, 1998), and analysts have identified the growth and opportunities in green markets as "the next big thing" for small business (Murphy, 2003). The increased availability of green products worldwide has also prompted numerous certification (or "ecolabeling") programs that are designed to verify the environmental claims of thousands of products in more than 31 countries.[1]

Economists have begun to investigate various empirical and theoretical topics related to these green-market trends. The majority of research in this growing literature tends toward one of two categories. The first is empirical research that seeks to determine the factors that influence consumer preferences and willingness to pay for particular green products.[2] The second is theoretical research that analyzes the effects of ecolabeling in the context of production decisions, information asymmetries, or international trade.[3] While the existing literature addresses many of the important questions surrounding the emergence of green markets, there has been no attempt thus far to develop the general consumer theory that underlies the consumption of all green products. As a result, questions remain about how demand for green products differs from standard theory, and how demand for green products is related to demand for environmental quality.

This paper begins to fill the gap in the literature by developing a general model of environmentally friendly consumption. The model begins with the observation that green products are impure public goods that generate both a private characteristic and an environmental public characteristic. Consider the example of shade-grown coffee, which is coffee grown under the canopy of tropical forests rather than in open, deforested fields. A conse-

[1] The Global Ecolabelling Network maintains a current list of green-product categories and criteria documents for all ecolabeling programs worldwide. This information is continually updated and is available online at http://www.gen.gr.jp.

[2] Examples include Blend and van Ravenswaay (1999); Teisl, Roe, and Levy (1999); Wessels, Johnston, and Donath (1999); and Teisl, Roe, and Hicks (2001).

[3] Examples include Nimon and Begin (1999); Mason (2000); Swallow and Sedjo (2000); and Dosi and Moretto (2001).

quence of this cultivation method, compared to that for conventional coffee, is that shade-grown plantations provide important refuges for tropical biodiversity, including migratory birds. Thus, consumers of shade-grown coffee purchase a joint product that generates coffee consumption (a private characteristic) and conservation of tropical biodiversity (a public characteristic). Other green products—such as green electricity, low-emission vehicles, and sustainably harvested forest products—reveal this same pattern of supplying both a private characteristic and an environmental public characteristic.

The model developed here is distinct from the standard impure public good model (Cornes and Sandler, 1984, 1994) because it considers the availability of substitutes for the impure public good. Specifically, the model accounts for the way that the jointly produced characteristics of the impure public good may be available separately as well. This possibility is important in the context of green products because consumers often have the opportunity to consume a conventional version of the good and/or make a donation to the associated environmental cause. Consumers of shade-grown coffee, for example, have additional opportunities to consume conventional coffee and to make donations to organizations such as Rainforest Alliance. With other green products, however, such substitute opportunities may be available for the private characteristic only, the public characteristic only, or neither. All of these potential green-market settings are considered in the model developed here, whereas the standard model applies only to settings with no substitute opportunities. This paper thus extends the literature on impure public goods, in addition to providing a framework for understanding environmentally friendly consumption.

The comparative static properties of the model generate the main results. Because utility functions are specified over characteristics of goods rather than over goods themselves, it is possible to distinguish between demand for a green product and demand for environmental quality. With this distinction, it is then possible to examine how changes in the exogenous parameters—including green-production technologies, market prices, and ambient environmental quality—affect not only demand for a green product, but also demand for environmental quality. It turns out, as will be shown, that these two sets of results can differ in important ways.

Several of the general findings are worth mentioning here in the introduction. First, the comparative static properties of the model are highly dependent on whether substitutes for the green product are available. This implies that, when analyzing environmentally friendly consumption, it is important to consider whether there exist alternative ways to obtain the jointly produced characteristics of a green product, that is, whether there is a conventional-good substitute and/or an opportunity to make a direct donation to the associated environmental cause. Second, the sign of some comparative static results are counterintuitive. For instance, decreasing the price of a green product or improving its technology can actually reduce demand for environmental quality. This surprising result occurs because increased consumption of a green product can crowd out direct donations to the associated environmental cause, with the net effect being a reduction in environmental quality. Finally, many of the comparative static results depend on whether the two characteristics of a green product are complements or substitutes in consumption. These findings demonstrate the importance clarifying the relationship between preferences for environmental quality and demand for green products.

The remainder of the paper is organized as follows. In the next section, I review the setup of Cornes and Sandler's (1984, 1994) impure public good model and show precisely how and why their model is extended in order to analyze the comparative statics of environmentally friendly consumption. In Sections 3 through 6, I use the model to analyze green-market scenarios that differ in terms of whether substitutes for the green product are available. In Section 7, I discuss general implications and extensions. Section 8 summarizes and concludes.

2 Preliminaries

The standard impure public good model is based on the characteristics approach to consumer behavior, which implies that consumers derive utility from characteristics of goods rather than from goods themselves.[4] Specifically, a representative consumer has preferences

[4]See Lancaster (1971) and Gorman (1980) for the pioneering work on this approach to modeling consumer behavior.

over three characteristics—Z, X, and Y—according to a utility function $U(Z, X, Y)$. Characteristics Z and X satisfy properties of a pure private good, while characteristic Y satisfies the non-rival and non-excludable properties of a pure public good. There are two market goods that generate characteristics. One of the goods generates only characteristic Z and is measured in units such that one unit of the good generates one unit of Z. This implies that the notation Z can be used to denote both the good and the characteristic. The other good, denoted g, generates both characteristics X and Y such that one unit of g generates $\alpha > 0$ units of X and $\beta > 0$ units of Y. It follows that the relationship between X and g is given by $X = \alpha g$. The relationship between Y and g is a bit more subtle, however. Because Y is a public characteristic, the consumer enjoys her own provision through consumption of g, in addition to the exogenous provision of other consumers and any other sources of Y (such as levels mandated by public policy). Thus, the relationship between Y and g is given by $Y = \beta g + \tilde{Y}$, where $\tilde{Y}$ denotes the exogenously given level of Y.

The good g is referred to as an impure public good because it generates both a private characteristic and a public characteristic. Impure public goods of this type have been interpreted in a variety of ways, with theoretical and empirical applications in the literature ranging from the economics of military alliances to models of philanthropy.[5] Here I interpret g as an environmentally friendly good or service (referred to hereafter as simply a "green product"). As discussed in the introduction, the distinguishing feature of a green product is joint production of a private characteristic (X) and an environmental public characteristic (Y).[6] With this interpretation, the impure public good model provides a framework to begin analyzing demand for green products. In particular, we can analyze how demand for g responds to changes in the green-product technologies (α and β) and exogenous environmental quality ($\tilde{Y}$), in addition to prices and income. Furthermore, by analyzing implicit demand for Y (which is determined by consumption of g), we can see how changes in these same parameters affect demand for environmental quality itself.

[5] Examples include Murdoch and Sandler (1984); Andreoni (1990); Sandler and Harley (2001); and Ribar and Wilhelm (2002).

[6] Later in the paper I discuss how all of the results apply equally to green products where the environmental characteristic is not a public good. I also discuss the related notion of "warm-glow" motives for green-product consumption.

There is, however, an important limitation of the standard impure public good model for analyzing environmentally friendly consumption. The model applies only if there are no substitutes for the green product, that is, if consuming g is the only way to obtain characteristic X and augment the level of characteristic Y. Yet this is unlikely to be the case in actual green-market settings. Typically, consumers have opportunities to purchase a conventional version of a green product, or to make a direct donation to the associated environmental cause, or to do both. It was mentioned earlier how consumers of shade-grown coffee have additional opportunities to purchase conventional coffee and to make donations to Rainforest Alliance. In the context of the model, we can now interpret shade-grown coffee as g, and recognize that conventional coffee also generates X, while donations to Rainforest Alliance also provide Y.

In what follows, I extend the comparative static analysis of the impure public good model to include these additional market alternatives. To account for all potential market settings involving consumption of g, I consider three alternative scenarios: (a) one with a conventional-good substitute that generates characteristic X, (b) one with the opportunity for donations that directly generate characteristic Y, and (c) one with both the conventional-good substitute and the opportunity for donations.[7] As part of the analysis, I compare the results of these scenarios to those of the standard model. It turns out, as we will see, that these different market scenarios have important implications for the consumption of impure public goods in general. And in particular, the results demonstrate how the comparative statics of environmentally friendly consumption depend on whether substitutes for green products are available.

3 Substitute Conventional Good

This section considers a green-market scenario where, in addition to a green product, consumers have the opportunity to purchase a conventional-good substitute. This scenario is

[7] Two other papers have extended the choice setting of the impure public good model. Vicary (1997) considers the possibility for donations, and Kotchen (2002) considers both donations and a private-good substitute. While the latter paper also focuses on green products, neither paper investigates the comparative static properties of the model in its extended form.

the most intuitive and straightforward to analyze. As a motivating example, consider a green-electricity program in which households can choose to have a portion of their electricity generated with renewable sources of energy. Green electricity is the impure public good (providing electricity consumption and a reduction in pollution emissions) and conventional electricity is the conventional-good substitute (providing electricity consumption only). It is assumed in this scenario that consumers do not have the opportunity to make direct donations to reduce emissions, although this possibility will be considered later.[8]

To model this choice setting, we need only modify the setup discussed in the previous section. In addition to the market goods Z and g, there is now a conventional good, denoted c, that generates characteristic X only. To ease notation, measure c in units such that one unit of c generates one unit of X. Furthermore, treat Z as a numeraire so that exogenously given prices p_c and p_g are in units of Z.

A representative consumer has exogenous income m and seeks to maximize a utility function that is quasilinear with respect to Z:

$$U(Z, X, Y) = Z + F(X, Y),$$

where $F(X, Y)$ is strictly increasing and strictly quasiconcave. While more general preferences can be accommodated easily, the quasilinearity assumption simplifies the analysis and enables focusing on the characteristics of interest, X and Y. The assumption also helps to demonstrate how the important insights—the diverse set of comparative static results—depend on substitution effects between X and Y, rather than on income effects.

With this setup, the consumer's utility maximization problem can be written as

$$\max_{Z,c,g} \left\{ Z + F(X, Y) \mid Z + p_c c + p_g g = m,\ X = c + \alpha g,\ Y = \beta g + \tilde{Y} \right\}. \tag{1}$$

Examining the solution to this problem reveals that consumption of c will never occur if $p_c \geq \frac{p_g}{\alpha}$. In this case, g provides each unit of X at a weakly lower price than c and has

[8] With green electricity, the assumption of no direct donations is reasonable if households are simply unaware that such opportunities exist, or if the public good is local air quality, in which case donation opportunities are exceedingly rare.

the additional benefit of generating a positive amount of Y. Thus, consuming c cannot be optimal, and the model reverts back to the standard impure public good model. The following assumption is made to rule out this possibility and thereby maintain the interesting case.

Assumption 1 $p_c < \dfrac{p_g}{\alpha}$.

In effect, Assumption 1 identifies a necessary condition for the viability of a conventional good when a green version is available. It is worth noting that the magnitude of α dictates the necessary relationship between prices. When $\alpha \geq 1$, the quality of c with respect to generation of X is weakly lower than that of g, and consumption of c will occur only if $p_c < p_g$. In contrast, when $\alpha < 1$, the quality of c is higher than that of g, and consumption of c is possible even if $p_c \geq p_g$.

An alternative and useful way to write the utility maximization problem has the consumer choosing characteristics directly, rather than indirectly through c and g. Substituting c and g out of problem (1) yields

$$\max_{Z,X,Y} \left\{ Z + F(X,Y) \mid Z + \pi_x X + \pi_y Y = m + \pi_y \tilde{Y},\ Y \geq \tilde{Y},\ \tfrac{X}{\alpha} \geq \tfrac{(Y-\tilde{Y})}{\beta} \right\},$$

where $\pi_x \equiv p_c$ and $\pi_y \equiv \frac{p_g - \alpha p_c}{\beta} > 0$ are the implicit prices of X and Y, respectively. The first constraint is the "full-income" budget constraint, where full income includes income plus the value of environmental-quality spillins. The second constraint requires that the chosen level of environmental quality be at least as high as that which is given exogenously. The third constraint is necessary because consuming $Y > \tilde{Y}$ requires consuming a minimum amount of X according to the parameters α and β that characterize g.

The budget frontier for this problem is represented by the plane ABC in Figure 1. The points A, B, and C correspond to the loci in characteristics space where income is spent entirely on c, g, or Z, respectively. Note that, in this market scenario, availability of the green product can only increase demand for environmental quality; for without g, the chosen point would be restricted to the line segment AC, and the level of environmental quality would always remain at $\tilde{Y}$.[9]

Let us now turn to the analysis of how changes in the exogenous parameters affect demand for environmental quality and demand for the green product. Assuming an interior solution with respect to characteristics (here and throughout), quasilinearity of the utility function implies that the consumer's demand for Y can be written as a function of the implicit prices only: $\hat{Y}^c = \hat{Y}^c(\pi_y, \pi_x)$, where the superscript references the market scenario that includes a conventional-good substitute.[10] With this function, it is straightforward to examine how changes in the exogenous parameters affect demand for environmental quality $\hat{Y}^c$. To simplify notation throughout this and subsequent sections, define $\hat{Y}^k_\theta \equiv \partial\hat{Y}^k/\partial\theta$, where θ is the parameter of interest in market scenario k. Furthermore, define $\hat{Y}^k_j \equiv \partial\hat{Y}^k/\partial\pi_j$ for $j = y, x$. Using these notational conventions, we can now examine the comparative statics of demand for $\hat{Y}^c$, and then derive results for demand for the green product using the relationship $\hat{g}^c = \frac{1}{\beta}\left(\hat{Y}^c - \tilde{Y}\right)$.

First consider changes in the market prices. The effect of a change in p_g on demand for environmental quality is

$$\hat{Y}^c_{p_g} = \frac{1}{\beta}\hat{Y}^c_y < 0.$$

The negative sign follows because an increase in the price of the green product increases the implicit price π_y of obtaining Y (which the consumer can obtain through g only). Then, because demand for Y is decreasing in π_y, demand for Y is decreasing in p_g as well. In other words, demand for environmental quality is decreasing in the price of the green product.

The effect of a change in p_c on demand for environmental quality is a bit more subtle:

$$\hat{Y}^c_{p_c} = -\frac{\alpha}{\beta}\hat{Y}^c_y + \hat{Y}^c_x. \tag{2}$$

Here the sign is generally ambiguous. To see why, consider an increase in p_c. One consequence is a decrease in π_y. This follows because an increase in p_c makes g relatively less expensive, which implies that obtaining Y is relatively less expensive. Another consequence

[9] We will return to other parts of Figure 1 in subsequent sections.

[10] The parameters m and $\tilde{Y}$ need not enter this function because, with the assumption of an interior solution, quasilinear preferences imply that full income has no effect on demand for Y.

is an increase in π_x, since the price of the conventional good determines the price of the private characteristic (i.e., $\pi_x = p_c$). The effects of these two consequences are captured, respectively, in the first and second terms on the right-hand side of equation (2). The sign of the first term is always positive because demand for Y is decreasing in its own price π_y. The sign of the second term, however, depends on whether X and Y are substitutes or complements, and it is either positive or negative, respectively. Thus, demand for environmental quality is increasing in p_c if X and Y are substitutes; otherwise, the sign of the effect of a change in p_c will depend on the degree of complementarity between the private and public characteristics.

Now consider changes in the technology parameters of the green product. A change in β changes the amount of Y generated by each unit of g. This, in turn, changes the implicit price of obtaining Y, and the effect on demand for Y has the opposite sign of a change in p_g:

$$\hat{Y}^c_\beta = -\frac{p_g - \alpha p_c}{\beta^2}\hat{Y}^c_y = -\pi_y \hat{Y}^c_{p_g} > 0.$$

To gain an intuition for this result, consider an increase in β. This has the effect of decreasing π_y because obtaining Y becomes less costly through consumption of g. While this is similar to the effect of a *decrease* in p_g, the difference is the weight π_y, which is the implicit price of the characteristic associated with β. The effect of a change in α on demand for environmental quality follows a similar pattern:

$$\hat{Y}^c_\alpha = -\frac{p_c}{\beta}\hat{Y}^c_y = -\pi_x \hat{Y}^c_{p_g} > 0$$

The only difference is that, relative to a change in p_g, the effect is weighted by π_x, which is the implicit price of the characteristic associated with α.

Finally, consider changes in income m and exogenous environmental quality $\tilde{Y}$. It turns out that changes in either of these parameters has no affect on demand for environmental quality. This follows because full income ($m + \pi_y \tilde{Y}$) has no effect on demand for Y, due to the assumptions of quasilinear preferences and of an interior solution with respect to characteristics. An implication of this result is that crowding-out of private provision of environmental quality is exactly one-for-one: a change in exogenous provision of Y is offset exactly by a change in the consumer's private provision of Y.[11]

Given the results for $\hat{Y}^c$, it is now straightforward to derive the comparative statics of demand for the green product. Using parallel notation and the technological relationship between $\hat{g}^c$ and $\hat{Y}^c$, we can express these results as

$$\hat{g}^c_\theta = \frac{1}{\beta}\left(\hat{Y}^c_\theta - \tilde{Y}_\theta\right),$$

where $\tilde{Y}_\theta \equiv d\tilde{Y}/d\theta$ and is equal to zero for changes in all parameters other than $\tilde{Y}$, in which case it equals 1. It follows from this expression that $\hat{g}^c_\theta$ has the same sign as $\hat{Y}^c_\theta$ and differs by only the scale factor $\frac{1}{\beta}$ for all parameters other than $\tilde{Y}$, in which case $\hat{g}^c_{\tilde{Y}} = -\frac{1}{\beta} < 0$. Note that this latter result shows how the crowding-out of private provision occurs with adjustments in g: an increase in exogenous environmental quality equal to $\Delta\tilde{Y}$ results in a decrease in $\hat{g}^c$ equal to $-\frac{\Delta\tilde{Y}}{\beta}$, and the net effect on environmental quality is equal to zero.

The first two columns of Table 1 summarize the qualitative results for both $\hat{Y}^c_\theta$ and $\hat{g}^c_\theta$. We will return to these results later as we consider different market scenarios.

4 Substitute Donations

This section analyzes a green-market scenario where a conventional version of the green product is *not* available, but there *is* the opportunity to make a direct donation to the associated environmental cause. Sustainably harvested products from tropical rainforests (such as nuts) provide a motivating example. While there may be no conventional-good substitutes for these products (such as similar nuts not from rainforests), aiding in the conservation of rainforests is possible not just through consumption of the sustainably harvested products, but also through direct donations to organizations such as Rainforest Alliance.

How do the comparative statics differ in this market scenario? We can answer this question by following steps similar to those in the previous section. In this case, the difference is that the standard model must be modified to include the option for a direct donation to

[11] Section 5 demonstrates that one-for-one crowding-out need not hold in all green-market scenarios, despite the assumptions of quasilinear preferences and of an interior solution.

Y. Let d denote a donation level that is measured in units of Y, and let p_d denote the price of providing a unit of Y through a direct donation.

The utility maximization problem for this market scenario can be written as

$$\max_{Z,g,d} \left\{ Z + F(X,Y) \mid Z + p_g g + p_d d = m,\; X = \alpha g,\; Y = \beta g + d + \tilde{Y} \right\}. \tag{3}$$

Just as an assumption was necessary in the previous section to maintain viability of c, an assumption is necessary here to maintain viability of d.

Assumption 2 $p_d < \dfrac{p_g}{\beta}$.

This assumption implies that increasing the level of Y through donations d is less costly than through consumption of g.[12] For without this condition, it would never be optimal to make a donation, and maximization problem (3) would be equivalent to that for the standard impure public good model.

We can now substitute g and d out of problem (3) and write the utility maximization problem in terms of implicit choices over characteristics:

$$\max_{Z,X,Y} \left\{ Z + F(X,Y) \mid Z + \mu_x X + \mu_y Y = m + \mu_y \tilde{Y},\; \tfrac{X}{\alpha} \leq \tfrac{(Y-\tilde{Y})}{\beta} \right\},$$

where $\mu_x \equiv \frac{p_g - \beta p_d}{\alpha} > 0$ and $\mu_y \equiv p_d$ are the implicit prices of X and Y in this scenario. The first constraint is the full-income budget constraint. The second constraint is necessary because consuming $X > 0$ necessarily augments Y above $\tilde{Y}$ by an amount that depends on the parameters α and β that characterize g. Note that the sign of the second constraint is the opposite of that in the previous scenario, and that the second constraint implies $Y \geq \tilde{Y}$ because $X \geq 0$.

The budget frontier for this problem is represented by the plane BDC in Figure 1. The points B, D, and C correspond to the loci in characteristics space where income is spent

[12] This assumption implicitly assumes after-tax prices for all goods in the model. It is interesting to note, however, that donations can be tax deductible, while expenditures on green products are often subject to sales tax. If we were to make these features explicit in the model, Assumption 2 could be written as $p_d(1-\delta) < \frac{p_g(1+\tau)}{\beta}$, where p_d and p_g are the pre-tax prices, δ is the marginal tax deduction, and τ is the marginal sales tax. The effect of both δ and τ is to make the assumption easier to satisfy.

entirely on g, d, or Z, respectively. An important difference from the previous market scenario is that availability of the green product will not necessarily increase demand for environmental quality. Without g, the budget frontier is simply the line segment DC, which implies no consumption of characteristic X. Yet with g, consumption of X is possible, and the expanded frontier includes potential allocations with both higher and lower levels of Y than are available on segment DC only.

Mirroring the order of the previous section, we can begin with the comparative statics of demand for environmental quality, and then derive results for the green product. Using parallel notation, demand for environmental quality is written as $\hat{Y}^d = \hat{Y}^d(\mu_y, \mu_x)$, and the effect of a change in p_g is

$$\hat{Y}^d_{p_g} = \frac{1}{\alpha}\hat{Y}^d_x.$$

The sign of this expression can be either positive or negative, depending on whether X and Y are substitutes or complements, respectively. Note that the possibility for $\hat{Y}^d_{p_g} > 0$ is somewhat counterintuitive. Intuition might suggest—as we saw earlier—that demand for environmental quality is decreasing in the price of the green product; however, this is not the case here if X and Y are substitutes.

It is worth emphasizing the reasoning behind this result. Consider a decrease in p_g. This decreases μ_x because obtaining X is less costly through consumption of g. The decrease in μ_x encourages substitution toward more X, and because X is a substitute for Y, demand for Y must decline. Hence, a decrease in the price of the green product results in a decrease in demand for environmental quality. But what must occur with consumption of g and d to yield this result? It turns out that demand for g increases and demand for d decreases such that the net effect on environmental quality is negative. This possibility gives rise to an important observation: an increase in demand for a green product does not necessarily improve environmental quality, as increased consumption of the green product can crowd-out direct donations.

Prior intuition can be similarly misleading when it comes to the effect of a change in the price of making a donation. A decrease in the price of providing environmental quality through donations is *not* necessarily beneficial for environmental quality. The analytical result of a change in p_d is

$$\hat{Y}^d_{p_d} = \hat{Y}^d_y - \frac{\beta}{\alpha}\hat{Y}^d_x,$$

and the sign of this expression is ambiguous. To see why, consider a decrease in p_d. This has two effects: a decrease in μ_y because providing Y becomes less expensive through d, and an increase in μ_x because obtaining X becomes relatively more expensive through g. The first effect unambiguously increases demand for environmental quality, but the second does so only if X and Y are substitutes. If, however, the two characteristics are complements, the net effect on environmental quality is ambiguous.

The effects on demand for environmental quality from changes in the technology parameters of the green product follow a pattern similar to that in the previous section. These results are

$$\hat{Y}^d_\beta = -\frac{p_d}{\alpha} = -\mu_y \hat{Y}^d_{p_g}$$

and

$$\hat{Y}^d_\alpha = -\frac{p_g - \beta p_d}{\alpha^2}\hat{Y}^d_x = -\mu_x \hat{Y}^d_{p_g}.$$

The sign of both expressions is the opposite of that for a change in p_g, and the magnitudes differ according to the implicit prices of the characteristics that correspond to the change in technology. The fact that the sign of both expressions is negative if X and Y are substitutes leads to another important observation: improving either the private- or public-characteristic technology of a green product can result in lower demand for environmental quality. In such cases, the improved efficiency of the green product discourages donations and encourages substitution, through the green product, toward greater consumption of the private characteristic.

The effect on demand for environmental quality from changes in income or exogenously given environmental quality is identical to that in the previous scenario: changes in m or $\tilde{Y}$ have no effect on demand for Y. One implication is that crowding-out of private provision of environmental quality is exactly one-for-one in both market scenarios.

We can now turn to the comparative statics of demand for the green product. Unlike the previous scenario, these results do not follow directly from those for $\hat{Y}^d$. This is because, in this scenario, implicit demand for environmental quality depends not only on demand for the green product, but also on donations (recall that $\hat{Y}^d = \beta\hat{g}^d + d + \tilde{Y}$). Thus, changes in $\hat{g}^d$ cannot be identified from changes in $\hat{Y}^d$ alone, as they also depend on changes in d. It is, however, possible to identify changes in $\hat{g}^d$ from changes in implicit demand for the private characteristic $\hat{X}^d = \hat{X}^d\left(\mu_x, \mu_y\right)$. Here we can use the technology relationship $\hat{X}^d = \alpha\hat{g}^d$ to express the comparative statics of demand for the green product as

$$\hat{g}^d_\theta = \frac{1}{\alpha}\hat{X}^d_\theta.$$

Because most of these results are symmetric to those in the previous section, they are not derived here; however, the qualitative results for $\hat{g}^d_\theta$ are reported in Table 1, along with those for $\hat{Y}^d_\theta$.

The only notable difference with respect to demand for the green product occurs with a change in $\tilde{Y}$, which has no affect on $\hat{g}^d$ in this market scenario. This follows because—as in models of private provision of a pure public good (e.g., Bergstrom, Blume, and Varian, 1986)—changes in exogenous provision are offset by changes in donations. For example, an increase in $\tilde{Y}$ results in a lower donation that, due to the one-for-one crowding-out, leaves environmental quality unchanged. Thus, because changes in $\tilde{Y}$ can be offset with changes in d in this market scenario, changes in exogenous environmental quality have no affect on demand for the green product.

5 No Substitutes

It is possible for the market to offer a green product, but *neither* a conventional-good substitute *nor* an opportunity to make a direct donation to the associated environmental cause. This green-market scenario is consistent with the setup of the standard impure public good model (Cornes and Sandler, 1984, 1994). This section describes how the comparative static results for this market scenario differ from those considered previously.

With choices over the green product and the numeraire only, the utility maximization problem can be written as

$$\max_{Z,g} \left\{ Z + F(X,Y) \mid Z + p_g g = m,\ X = \alpha g,\ Y = \beta g + \tilde{Y} \right\}. \tag{4}$$

Again, it is useful to transform the maximization problem to consider implicit choices over characteristics. Substituting g out of problem (4) yields

$$\max_{Z,X,Y} \left\{ Z + F(X,Y) \mid Z + \frac{p_g}{\alpha} X = m,\ \tfrac{X}{\alpha} = \tfrac{(Y-\tilde{Y})}{\beta} \right\}$$

The budget frontier for this problem is defined by two linear constraints and is represented by the line segment BC in Figure 1. The points B and C correspond to the loci in characteristics space where all income in spend on either g or Z, respectively. Note that BC corresponds to the boundary between the budget frontiers of the two previous scenarios.

The fact that the budget frontier is a line segment in (Z,X,Y) space, rather than a plane, has important implications for the comparative static analysis. Unlike the previous scenarios, we cannot calculate directly the implicit prices of characteristics X and Y. Consequently, the analysis must rely on "virtual" prices that correspond to the marginal rate of substitution with respect to the numeraire at the chosen point on segment BC. These virtual prices are functions of the exogenous parameters and can be written as $\varphi_j = \varphi_j(\Theta)$ for $j = y, x$, where Θ denotes the vector of parameters $(p_g, \alpha, \beta, \tilde{Y}, m)$. The Appendix includes a detailed description of how these virtual prices are derived. For the present purposes, however, it is sufficient to recognize that demand for environmental quality can be written as a function of these prices: $\hat{Y}^g = \hat{Y}^g(\varphi_y, \varphi_x)$, where the superscript g denotes the scenario with no substitutes for the green product.

Following steps similar to those in the previous sections, we can now examine how changes in the exogenous parameters affect demand for environmental quality. Letting θ denote any one of the exogenous parameters, all of the results can be expressed generally as

$$\hat{Y}^g_\theta = \hat{Y}^g_y \varphi_{y\theta} + \hat{Y}^g_x \varphi_{x\theta}, \tag{5}$$

where $\varphi_{j\theta} = \partial\varphi_j/\partial\theta$ for $j = y, x$. Drawing on the work of Cornes and Sandler (1994, 1996), it is straightforward, although a bit tedious, to solve equation (5) explicitly for a change in each of the different parameters θ. The Appendix reports all of these results, along with a sketch of the necessary steps for their derivation. Here, it is more useful to focus on the qualitative results and see how they differ from the other market scenarios.

The last two columns of Table 1 summarize these results. In this scenario, demand for environmental quality is always decreasing in the price of the green product. This follows because both of the characteristics X and Y are available through consumption of g only. Thus, an increase in p_g, for example, will increase the price of obtaining both X and Y, and the result will be substitution away from consumption of X and Y and toward consumption of Z.

The most striking feature of the other results for the effects on demand for environmental quality is the fact that many of the signs are ambiguous. The reason stems from the way that consumers have little flexibility to choose their mix of characteristics. Feasible allocations are restricted to the line segment BC, and the only possible response to a change in an exogenous parameter is a change in consumption of g. Accordingly, changes in demand for Y are inseparable from changes in demand for X, and this inseparability introduces a degree of ambiguity in the comparative statics of demand for Y that was nonexistent in the previous market scenarios.

One consequence of the inseparability of X and Y that is worth noting relates to the crowding-out of private provision of environmental quality. We saw in the previous market scenarios that changes in $\tilde{Y}$ have no effect on demand for environmental quality, as changes in private provision will offset exactly changes in $\tilde{Y}$. Without substitutes for g, however, such one-for-one crowding-out will not generally occur. This follows because, unlike the previous scenarios, changes in private provision of Y must be accompanied by changes in consumption of X. As a result, it can be shown that an increase (decrease) in $\tilde{Y}$ results in an increase (decrease) in demand for environmental quality if X and Y are substitutes, in which case crowding-out is less than one-for-one. If X and Y complements, however, changes in $\tilde{Y}$ have an ambiguous effect on demand for environmental quality, and thereby an ambiguous effect on the degree of crowding-out.

The last two columns of Table 1 also summarize the different effects on demand for the green product. These follow directly from equation (5) using the relationship

$$\hat{g}_\theta^g = \frac{1}{\beta}\left(\hat{Y}_\theta^g - \tilde{Y}_\theta\right).$$

It follows that all of the results for $\hat{g}_\theta^g$, with the exception of $\hat{g}_{\tilde{Y}}^g$, have the same sign as the corresponding result for $\hat{Y}_\theta^g$. Changes in $\tilde{Y}$ will be an exception when $0 < \hat{Y}_{\tilde{Y}}^g < 1$, which is the case of incomplete crowding-out. In this case, an increase in $\tilde{Y}$ results in greater demand for environmental quality, but demand increases by less than the exogenous supply. As a result, private provision $(\hat{Y}^g - \tilde{Y})$ decreases, which implies a decrease in demand for the green product. In this particular case, therefore, the comparative static of $\hat{g}_{\tilde{Y}}^g$ will have the opposite sign of that for $\hat{Y}_{\tilde{Y}}^g$.

6 Substitute Conventional Good and Donations

The most general market scenario involving a green product is one that offers both a conventional-good substitute *and* the opportunity to make a direct donation to the associated environmental cause. The example of shade-grown coffee was mentioned earlier, along with the additional opportunities to purchase conventional coffee and to make a donation to Rainforest Alliance. This section examines the comparative statics of environmentally friendly consumption in this general green-market scenario. As we will see, the analysis relies on all of the results in the previous sections.

With the complete choice setting—involving Z, c, g, and d—the utility maximization problem can be written as

$$\max_{Z,c,g,d}\left\{Z + F(X,Y) \mid Z + p_c c + p_g g + p_d d = m,\ X = c + \alpha g,\ Y = \beta g + d + \tilde{Y}\right\}. \quad (6)$$

It is straightforward to show that Assumptions 1 and 2 are still necessary to maintain the possibility for consumption of c and for a donation d. In this case, a third assumption is also necessary to maintain the possibility for consumption of g.

Assumption 3 $p_g < \alpha p_c + \beta p_d$.

This assumption ensures that the cost of obtaining characteristics X and Y jointly through g is less than the cost of obtaining them separately through c and d.[13] Without Assumption 3, and thereby viability of g, the model would be equivalent to the standard model of private provision of a *pure* public good (e.g., Bergstrom, Blume, and Varian 1986). Assumption 3 also ensures a unique solution to maximization problem (6). For if it were the case that $p_g = \alpha p_c + \beta p_d$, a unique solution would not be guaranteed, as different bundles of goods could generate the same quantities of characteristics at the same cost.

An important implication of the viability of the green good—through Assumption 3—is that the solution to problem (6) will never include both consumption of c *and* a donation d. This follows because any combination of X and Y that arises with positive amounts of c and d could be obtained at a lower cost by increasing g and reducing c and d. Therefore, interior solutions with respect to characteristics will involve consumption of g up to the point where demand for X or Y is satisfied, along with consumption of c, *or* donations d, *or* neither.

The fact that the solution to problem (6) will never include both consumption of c and a donation d implies that we can rewrite the budget constraint as satisfying two inequality constraints: $Z + p_c c + p_g g \leq m$ and $Z + p_g g + p_d d \leq m$. Using these constraints and substituting c, g, and d out of problem (6), we can rewrite the maximization problem in terms of implicit choices of characteristics:

$$\max_{Z,X,Y} \left\{ Z + F(X,Y) \mid Z + \pi_x X + \pi_y Y \leq m + \pi_y \tilde{Y},\ Z + \mu_x X + \mu_y Y \leq m + \mu_y \tilde{Y},\ Y \geq \tilde{Y} \right\},$$

where π_j and μ_j are the implicit prices defined in the previous sections. The budget frontier for this problem is represented in Figure 1 by both of the planes ABC and BDC. Without a donation, the first budget constraint will bind, and the chosen point will lie somewhere on the plane ABC. Without consumption of the conventional-good substitute, the second

[13] Referring back to the tax policies mentioned in footnote 12, Assumption 3 could also be modified to take account of sales taxes and tax-deductible donations. This would imply $p_g(1+\tau) < \alpha p_c(1+\tau) + \beta p_d(1-\delta)$, which demonstrates how both sales taxes and tax-deductible donations make it more difficult for green products to be viable.

budget constraint will bind, and the chosen point will lie somewhere on the plane BDC. Finally, with neither a donation nor consumption of the conventional-good substitute, both budget constraints will bind, and the chosen point will lie somewhere on the line segment BC. Note the direct correspondence between these three cases and the more restricted market scenarios that were considered previously.

We can rely on results from the previous sections to derive the comparative static properties of this more general version of the model. Denote demand for environmental quality as $\hat{Y} = \hat{Y}\left(p_c, p_g, p_d, \alpha, \beta, \tilde{Y}, m\right)$, where there is no superscript in this general scenario. Then, for a change in any parameter θ, the comparative statics of demand for environmental quality can be written as

$$\hat{Y}_\theta = \begin{cases} \hat{Y}_\theta^c & \text{if } \hat{c} > 0 \text{ and } \hat{d} = 0 \\ \hat{Y}_\theta^d & \text{if } \hat{c} = 0 \text{ and } \hat{d} > 0 \\ \hat{Y}_\theta^g & \text{if } \hat{c} = 0 \text{ and } \hat{d} = 0. \end{cases}$$

Furthermore, the comparative statics of demand for the green product can be written as

$$\hat{g}_\theta = \begin{cases} \hat{g}_\theta^c & \text{if } \hat{c} > 0 \text{ and } \hat{d} = 0 \\ \hat{g}_\theta^d & \text{if } \hat{c} = 0 \text{ and } \hat{d} > 0 \\ \hat{g}_\theta^g & \text{if } \hat{c} = 0 \text{ and } \hat{d} = 0. \end{cases}$$

These expressions demonstrate how the comparative static results of the previous market scenarios are special cases of the results for the general market scenario that includes both a conventional-good substitute and donations. The effect of changes in the exogenous parameters will depend on whether the initial consumption bundle includes consumption of the conventional-good substitute, or a direct donation, or neither. We saw previously how each set of results in Table 1 corresponds to one of the more restrictive market scenarios; now we can see how each set of results also corresponds to the special cases that may arise in the general market scenario.

7 Discussion

The previous sections demonstrate how the comparative statics of environmentally friendly consumption depend on the availability of substitutes for green products. But why might the jointly produced characteristics of a green product be available separately in some cases, but not in others? One possible explanation—as in the case of rainforest nuts—is that close substitutes are simply nonexistent. Another possible explanation has to do with technological efficiency. Assuming competitive markets, where prices equal marginal costs, Assumptions 1 through 3 identify technology requirements for market viability of c, d, and g, respectively. If any of these conditions are not satisfied, the corresponding good is technologically inefficient at generating its characteristics, and we would not expect the market to offer such alternatives.

Looking across the rows of Table 1, the effects of price changes on demand for the green products are generally as one would expect. The demand function is downward sloping, and changes in the price of other goods can either increase or decrease demand. The effect of changes in the green-product technologies are also intuitive in cases with simultaneous consumption of the conventional-good substitute or direct donations; improvements in either of the technologies of the green product increase demand for it. These intuitive results do not necessarily apply, however, in the most restrictive case involving consumption of the green product only.

What do we learn from the comparative statics of demand for environmental quality? An important insight is that intuitive results for green products do not necessarily imply intuitive results for environmental quality. Consider the case where the jointly produced characteristics of the green product are substitutes and there are donations. The results show that a decrease in the price of the green product or improvements in either of its technologies will actually reduce demand for environmental quality. These counterintuitive results follow because such changes in the exogenous parameters not only increase demand for the green product; they also decrease the implicit price of its private characteristic, which is a substitute for environmental quality. Thus, demand for environmental quality decreases, and this is accomplished through a reduction in donations that more than offsets the increase in environmental quality from green-product consumption. This possibility highlights the importance, when considering the likely effects of green-product consumption on environmental quality, of taking into account (i) whether the characteristics of green products are substitutes or complements in consumption, and (ii) the interaction between the consumption of green products and direct donations to improve environmental quality.

The comparative static results also provide insight into the potential effectiveness of environmental policy in the context of environmentally friendly consumption. Consider policies based on public provision of environmental quality.[14] We can understand the positive (as opposed to normative) effects of these policies by examining the effect of increases in $\tilde{Y}$. First consider cases involving consumption of c or donations d. The comparative statics for g imply that, in response to the public provision, green-product consumption will not increase and may decrease. This follows because public provision of environmental quality reduces the incentive for private provision. In fact, the comparative statics for Y imply that public provision crowds out private provision completely. In these cases, therefore, environmental policy based on public provision of environmental quality will have no effect on environmental quality. This is not, however, the general result in cases without consumption of c or d. With consumption of g only, the neutrality breaks down, and there is a potential role for policies based on public provision to affect environmental quality.[15]

The last two points for discussion extend the interpretation of the model. The first extension considers an alternative way to interpret the parameter β. Rather than view β as representing a technology, we can think of it as representing the level of awareness that consumers have about the environmental benefits associated with a particular good or service. With no awareness, $\beta = 0$, and consumers perceive green products to be conventional products that are characterized by α only. With greater awareness, β increases, and the comparative static analysis demonstrates the potential effects on product demand and environmental quality. To the extent that green marketing and ecolabeling programs are intended to increase awareness, the model thus provides a framework for understanding

[14] Examples include a lump-sum tax where the revenues are used to provide environmental quality, or a standard the increases the level of environmental quality.

[15] Such opportunities for public policy are discussed further by Cornes and Sandler (1994) in the context of the standard impure public good model.

the relationship between environmental information about goods and services and environmentally friendly consumption. Developing this perspective is important, as economists and policymakers are coming to view information-based approaches as the third wave of environmental policy, following the first wave of command-and-control regulations and the second wave of market-based instruments (Tietenberg, 1998).

The second extension of the model considers alternative motives for the consumption of green products. Throughout this paper, we have interpreted green products as impure public goods. This implies that green-product consumption is a form of private provision of an environmental public good. But what if the jointly produced characteristics of a green product generate private benefits only? For instance, the relevant characteristics of organic produce may be nutrition and fewer risks to personal health from pesticides—both of which are private benefits. It is also possible that consumers who purchase green products do so because it simply makes them feel good about "doing their part" to protect the environment. In other words, green-product consumption may be motivated by "warm glow," rather then provision of a public good.[16] It turns out that the model is useful for analyzing these cases as well. We need only reinterpret Y as another private characteristic—such as health benefits or warm glow—and set $\tilde{Y} = 0$, since there are no spillins of a private characteristic. With these modifications, all of the comparative static results remain unchanged.

8 Conclusion

This paper develops a general model of environmentally friendly consumption. It begins with the observation that green products can be interpreted generally as impure public goods, with joint production of a private characteristic and an environmental public characteristic. The model is distinct from existing treatments of impure public goods because it considers the availability of substitutes. Specifically, there is consideration of different market scenarios in which the jointly produced characteristics of a green product are available separately as well—through a conventional-good substitute, direct donations to improve environmental quality, or both.

[16] See Andreoni (1990) for further discussion of warm-glow motives for private provision of public goods.

The comparative static properties of the model generate the main results and provide a theoretical foundation for understanding how demand for a green product and demand for environmental quality depend on market prices, production technologies, and exogenously given environmental quality. The sign of many of the comparative static results depend on the availability of substitutes for the green product, especially on whether there are opportunities to make a direct donation to the associated environmental cause. Furthermore, the sign of many results depends to a large extent on whether consumer preferences are such that the jointly produced characteristics of a green product are substitutes or complements in consumption. Taken as whole, the analysis extends the literature on impure public goods, in addition to providing a number of insights into the relationship between demand for green products and demand for environmental quality. Among these results are the surprising findings that increased demand for a green product or improvements in a green product's technology can have detrimental effects on environmental quality.

Future research should consider empirical applications of the model. All of the comparative static results generate testable hypotheses. Indeed, there are an increasing number of opportunities for empirical studies, as markets for green products continue to expand, along with programs designed to increase the awareness of environmental information on goods and services. Combining the theoretical analysis of this paper with empirical evidence would generate insight into the ways in which markets for green products actually affect environmental quality. The combined perspective would also improve the understanding of the relationship between environmentally friendly consumption and public policies for environmental protection.

9 Appendix

Cornes and Sandler (1996) provide a detailed discussion of the methodology for deriving comparative statics for the standard impure public good model. This Appendix reproduces the relevant steps of their analysis with two modifications: the approach is simplified for the case of quasilinear preferences, and there is no normalization such that $\alpha = \beta = 1$.

The first step is to solve for the virtual prices for X and Y, which can be written as a function of the exogenous parameters: $\varphi_j = \varphi_j(\Theta)$ for $j = x, y$ and $\Theta \equiv (p_g, \alpha, \beta, \tilde{Y}, m)$. These virtual prices must satisfy two conditions. The first is

$$\alpha\varphi_x + \beta\varphi_y = p_g, \tag{7}$$

which follows because the value of characteristics generated by a unit of g must be equal to the value of a unit of g. The second is

$$\beta\hat{X}^g(\varphi_x, \varphi_y) = \alpha\left[\hat{Y}^g(\varphi_y, \varphi_x) - \tilde{Y}\right], \tag{8}$$

which follows directly from the technology of the green product. Equations (7) and (8), along with the known quantities $\hat{X}^g$ and $\hat{Y}^g$, implicitly define the two unknown virtual prices φ_x and φ_y.

Now the goal is to analyze how changes in the exogenous parameters affect demand for environmental quality. Letting θ denote any one of the parameters, all of the results can be expressed generally as

$$\hat{Y}^g_\theta = \hat{Y}^g_y\varphi_{y\theta} + \hat{Y}^g_x\varphi_{x\theta}, \tag{9}$$

which is the same equation (5) in the text. In order to make this expression comparable with those from previous market scenarios, we must solve for $\varphi_{y\theta}$ and $\varphi_{x\theta}$. This is accomplished by differentiating (7) and (8) with respect to θ and solving for $\varphi_{y\theta}$ and $\varphi_{x\theta}$ using Cramer's rule. Then, substituting these expressions into (9) yields the effect on demand for environmental quality given a change in any parameter θ.

First consider a change in p_g. Following the steps above, the effect on demand for environmental quality is

$$\hat{Y}^g_{p_g} = \frac{\hat{X}^g_y \hat{Y}^g_x - \hat{X}^g_x \hat{Y}^g_y}{} < 0,$$

where $\equiv \alpha \hat{Y}^g_x - \frac{\alpha^2}{\beta} \hat{Y}^g_y - \beta \hat{X}^g_x + \alpha \hat{X}^g_y$. Intuition for why the sign of this expression is negative follows from the fact that demand for g is generally downward sloping.[17] This, in turn, implies that demand for Y is decreasing in p_g as well, since Y is available through consumption of g only.

For reasons that will be come clear, it is convenient to consider a change in $\tilde{Y}$ before considering changes in the technology parameters. The effect on demand for environmental quality from a change in $\tilde{Y}$ is

$$\hat{Y}^g_{\tilde{Y}} = \frac{-\frac{\alpha^2}{\beta} \hat{Y}^g_y + \alpha \hat{Y}^g_x}{}.$$

In order to sign this expression, we must first recognize that the denominator is not negative and is assumed to be positive.[18] Then, since $\hat{Y}^g_y < 0$, the only unknown sign relates to $\hat{Y}^g_x$, which depends on whether X and Y are substitutes or complements. If they are substitutes, the sign of the overall expression is positive. If they are complements, the sign of the expression is ambiguous.

Now consider changes in the technology parameters of the green product. Solving for the effect of a change in β and simplifying yields

$$\hat{Y}^g_\beta = -\varphi_y \hat{Y}^g_{p_g} + \frac{1}{\beta} \left(\hat{Y}^g - \tilde{Y} \right) \hat{Y}^g_{\tilde{Y}}.$$

Relying on the results above, it is easy to see that the sign of this expression is positive if X and Y are substitutes; otherwise, the sign is ambiguous. The effect of a change in α follows a similar pattern:

$$\hat{Y}^g_\alpha = -\varphi_x \hat{Y}^g_{p_g} - \frac{1}{\alpha} \left(\hat{Y}^g - \tilde{Y} \right) \hat{Y}^g_{\tilde{Y}}.$$

[17] See Cornes and Sandler (1996) for an explanation of why downward sloping demand for g follows from strict quasiconcavity of preferences over characteristics X and Y.

[18] To show that ≥ 0, consider the matrix of compensated price responses. Denote this matrix C and arrange it such that the first, second, and third rows correspond to Z, X, and Y, respectively. A standard result of microeconomic theory is that C is negative semidefinite (see Varian, 1992). This implies that $\lambda^T C \lambda$ is nonpositive for all vectors λ. Letting $\lambda \equiv (0, \beta, -\alpha)$, it follows that $-\beta \quad \leq 0$ or equivalently ≥ 0, which is assumed to hold with a strict inequality.

In this case, however, the second term on the right hand side has the opposite sign as a change in $\tilde{Y}$. As a result, the sign of the overall expression is ambiguous regardless of whether X and Y are complements or substitutes.

Finally, consider a change in income m. Solving for the changes in virtual prices yields $\varphi_{ym} = \varphi_{xm} = 0$. It follows that $\hat{Y}_m^g = 0$, which, as we have seen before, is the result of the assumptions of quasilinear preferences and of an interior solution with respect to characteristics.

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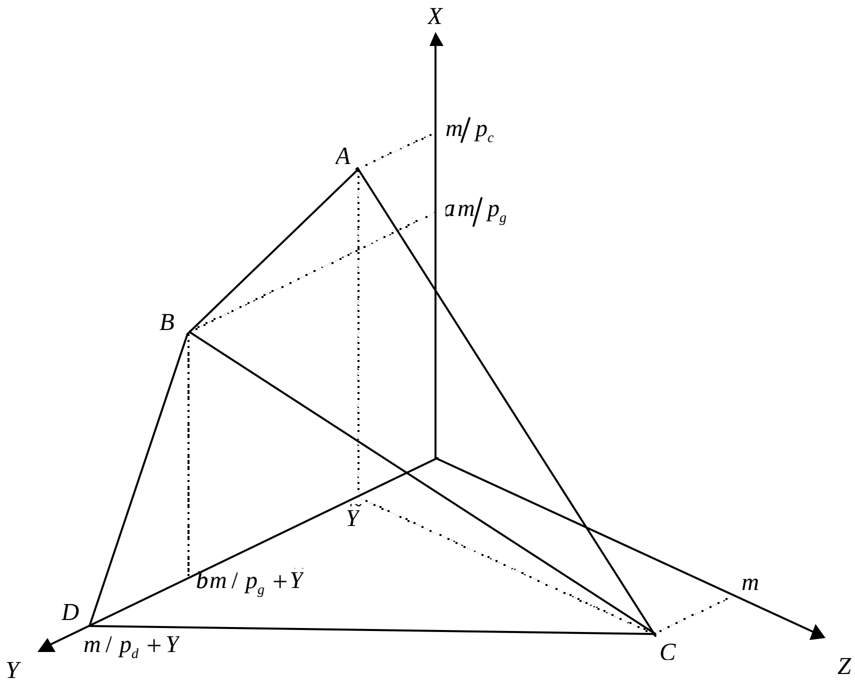

Figure 1: Budget frontiers in characteristics space

Table 1: Summary of qualitative comparative static results

	c and g[a]		d and g		g only	
	substitutes[b]	complements	substitutes	complements	substitutes	complements
$\hat{Y}_{p_g}$	-	-	+	-	-	-
$\hat{Y}_{p_c}$	+	?	na	na	na	na
$\hat{Y}_{p_d}$	na[c]	na	-	?	na	na
$\hat{Y}_{\beta}$	+	+	-	+	+	?
$\hat{Y}_{\alpha}$	+	+	-	+	?	?
$\hat{Y}_{\tilde{Y}}$	0	0	0	0	+	?
$\hat{g}_{p_g}$	-	-	-	-	-	-
$\hat{g}_{p_c}$	+	?	na	na	na	na
$\hat{g}_{p_d}$	na	na	+	?	na	na
$\hat{g}_{\beta}$	+	+	+	+	+	?
$\hat{g}_{\alpha}$	+	+	+	+	?	?
$\hat{g}_{\tilde{Y}}$	-	-	0	0	?	?

[a] This row indicates goods that are available in the market in addition to the numeraire Z.

[b] This row indicates whether the characteristics X and Y are substitutes or complements in consumption.

[c] na stands for not applicable in the corresponding market scenario.