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Eco-Labeling and Stages of Development

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Abstract

The paper examines the effectiveness of eco-labeling in providing a market-based solution to the under-consumption of eco-friendly products in developing and developed countries. The authors show that whether labeling is an effective device in solving the problem of asymmetric information between sellers and buyers, or whether false labeling severs the link between willingness to pay and environmental conscious production choices, depends crucially on how monitoring intensities respond endogenously to economic growth, openness to trade, and technology transfers. In particular, by accounting for endogenous policy responses to economic growth, it is shown that an inverted-U relationship exists between consumer spending on eco-unfriendly products and national income. In addition, while international trade unambiguously benefits the environment in the presence of eco-labeling with perfect enforcement, trade openness may nevertheless delay the turning point of the growth and environment relationship, when the cost of enforcement falls disproportionately on developing countries, and when environmental policies are employed to reap terms-of-trade gains.

1. Introduction

"Eco-labeling," defined as a practice of providing information to consumers about a product which is characterized by improved environmental performance and efficiency compared with similar products, has gained increasing popularity in recent years. Germany's "Blue Angel" label, launched in 1978 to denote "environmentally friendly" products, was a pioneering eco-labeling effort. Since then, products with labels promoting attributes like "recyclable," "degradable" or "ozone-friendly" have flooded the market. More recently, products with eco-labels promoting environmentally friendly process and production methods (PPMs) like "dolphin-safe tuna," furniture made from wood harvested from sustainably managed forests, and fish from sustainable fisheries have also entered the market. Consequently, as Table 1 shows, there has been a notable increase in developing country participation in initiating voluntary eco-labeling programs since 1991. In the meantime, consumer awareness regarding eco-labeled products has also grown substantially. Results of surveys and opinion polls conducted in Japan, Singapore, Canada, and Norway, for example, show that the awareness of national eco-labels had increased by more than 50% only a few years after their introduction; while surveys in developing countries like India, South Korea, Chile, and Mexico have found that consumers would be willing to accept higher prices for environmentally friendlier products (Shams, 1995).

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Table 1. Voluntary Eco-labeling of Retail Products in Selected Countries

	Seal	*Year founded*	*No. of product categories*
Austria	Austrian Eco-Label	1991	35
Brazil	ABNT	1993	2
Canada	Environmental Choice	1988	49
China	Ecomark	1994	12
Croatia	Croatia's Environmental Label	1993	33
Czech Rep.	—	1994	17
Nordic countries	Nordic Swan	1989	42
EU	European Union Ecolabel Award Scheme	1992	11
France	NF-Environment	1992	6
Germany	Blue Angel	1977	88
Germany	Green Dot	1990	7
India	Ecomark	1991	16
Indonesia	BAPEDAL	1995	n.a.
Japan	Ecomark	1989	69
Korea	Ecomark	1992	36
Malaysia	Product Certification Program	1996	1
Netherlands	Stichting Mileukeur	1992	32
New Zealand	Environmental Choice	1990	17
Singapore	Green Label	1992	21
Thailand	Thai Green Label	1993	6
US	Energy Star	1992	26

Source: WTO (2000).

The popularity of eco-labeled products is primarily based on the market-driven approach to achieving environmental goals. The increased concern of consumers for the environment and food safety, reflected by their willingness to pay relatively higher prices for products that has been produced in an environmentally friendly manner, provides a positive incentive for producers to choose techniques that minimize the adverse effects on the environment and improve the quality of final products. However, this popularity is not without controversy. Many developing countries are afraid of losing market access for their products that often do not meet existing PPMs in developed countries since information about production methods, contained in labels, can shift consumers' demand away from a country's product that has not qualified for the eco-label. In view of the resulting adverse terms-of-trade consequences for developing countries, eco-labeling has become a much debated topic within the context of the World Trade Organization (Nordström and Vaughan (1999), United Nations (1997), WTO (2000)).

The growing popularity of national efforts to promote eco-labeling notwithstanding, important questions remain as to how voluntary labeling programs can be credibly designed. While the primary purpose of labeling is to assist consumption decisions by providing product information that consumers value as a private good, market responses to eco-labeling, along with the question of whether deliberate policy action would be required to guide both producers and consumers to make efficient decisions regarding labeling, remains largely unanswered. The theoretical literature on eco-labeling is sparse and no clear policy conclusions can be drawn from those that exist. Notable are studies by Srinivasan (1995) and Brown et al. (1996). Both these studies consider cases of domestic market failure in developing countries that lead to ecologically unfriendly production, and conclude that methods like tax/subsidy schemes imposed by governments can help mitigate the problem. Srinivasan's analysis is particularly relevant since it allows for moral considerations in the consumers' utility functions that allows them to express their environmental concerns through a greater willingness to pay for goods that are eco-friendly. Mattoo and Singh (1997), on the other hand, consider the adverse effects of labeling. Since labeling transforms previously homogenous products into differentiated ones (eco-friendly and unfriendly), demand for both eco-friendly and unfriendly products can rise thereby leading to the possibility that the increase in production of eco-unfriendly goods outweighs the corresponding increase in eco-friendly products in the developing countries.

The obvious difficulty associated with providing credible monitoring of eco-labeling programs raises the additional issue of false-labeling induced by the very green premium that is presumed to entice producers to adopt eco-friendly production processes. In this respect, Bureau et al. (1999) and Marette et al. (1999) adopt the notion of *credence goods* in the sense of Nelson (1970) and Akerlof (1970), and consider cases where adverse selection arising from imperfect information necessitates quality signaling. Bureau et al. show that trade liberalization that allows for potential entry of lower-quality goods induces high-quality producers to test and signal their true quality, thereby leading to an improvement in consumer welfare.[1] However, since these studies take the distribution of firms within each quality type (high and low) as exogenous, the question of costly monitoring and the possibility of false labeling in the scenario where firms endogenously choose quality levels remains to be addressed. In addition, the proliferation of eco-labeling schemes in agriculture, forestry, and other resource-based sectors also implies that oligopolistic market conduct may not apply.

In this context, in sections 2 and 3 we present a basic North–South model where consumers in the developed country (North) value the eco-friendless of imports from the developing country (South). In the absence of eco-labeling, consumers are unable to decipher products that are made via eco-unfriendly methods from eco-friendly ones. The basic setup thus allows for an understanding of how the green premium endogenously emerges depending on the consumers' willingness to pay, the developing economy's openness to trade, the stage of economic development of the country in question, and the degree of monitoring that producers who adopt eco-labeling are subject to. We provide formal arguments which show, in contrast to a situation with asymmetric consumer information in the absence of labeling, that eco-labeling with perfect enforcement guides both consumers and producers to the efficiency frontier of the developed and developing countries. Interestingly, the endogenous price premium thus generated implies that eco-friendly products are normal while eco-unfriendly products are inferior goods in general equilibrium. As a result, income gains achieved via international trade can be beneficial only to the environment as consumers shift demand away from the eco-unfriendly product consequent upon an increase in income.

In sections 4 and 5, these results are contrasted against a more realistic scenario with costly enforcement, to be borne by the developing country. We show that unless monitoring efforts keep pace with either indigenous economic growth or income gains via international trade, eco-unfriendly products become normal goods in general equilibrium precisely as false labeling rises and falls with consumer income. In this context, we find that the incentives on the part of developing economies to credibly enforce national eco-labeling schemes have a threshold property—costly monitoring strictly benefits a developing economy only when national income exceeds a critical threshold. This finding, regarding the role of the critical income threshold in determining the effectiveness of eco-labels in reducing eco-unfriendly products, explains why eco-labeling programs have not gained momentum in the majority of developing countries and provides a theoretical foundation for the empirical findings of Grossman and Krueger (1995) who show that economic growth brings an initial phase of environmental deterioration followed by a subsequent phase of improvement. Grossman and Krueger estimate that this turning point comes, in most cases, before a country reaches a per-capita income of US $8000.

It is of interest to note that our results regarding the effectiveness of eco-labeling in promoting the supply of eco-friendly products under imperfect monitoring can be contrasted with the findings of Copeland and Taylor (1994) regarding the impact of income growth and trade on the incidence of pollution, and hence on the environment. In particular, by decomposing the effects of income growth into scale, technical, and composition effects, Copeland and Taylor show that economic growth in the developed countries (North) increases the technological gap between the North and the developing countries (South), and has the effect of increasing the incidence of world pollution as dirty industries get concentrated in the South. Income growth in the South, on the other hand, reduces the technological gap between the trading partners and reduces world pollution—a finding that is confirmed by Antweiler et al. (2001).

In contrast, we show that eco-labeling allows for the endogenous emergence of a green premium that increases in response to income growth in either the North or the South. However, this increase in the green premium may not be sufficient to ensure that producers choose eco-friendly production techniques when monitoring of labels is imperfect. We show that below a critical Southern threshold income, Southern welfare is decreasing in the monitoring intensity on products labeled eco-friendly originating from the South. Further, the monitoring intensity is endogenous rather than determined through deliberate government action and depends on the economy's openness to trade, the cost-effectiveness of monitoring technologies, and the incentives for the developing country to suppress environmental objectives in order to achieve terms of trade gains. Consequently, in this earlier phase of economic growth, the South will not devote any resources to monitoring. Thus income growth, either indigenous or trade-induced, has the effect of increasing the supply of eco-unfriendly products in consonance with rising consumer expenditure.

On the other hand, Southern welfare improves with the monitoring intensity on eco-labeled products as Southern income exceeds the critical threshold. In this latter phase, if the fall in supply of eco-unfriendly products in response to increased monitoring outweighs the increased consumer expenditure on eco-unfriendly products, eco-labeling serves the objective of increasing the supply of eco-friendly products in general equilibrium—a result akin to Copeland and Taylor's findings on the environmental impact of growth in Southern income. These observations suggest that wholesale promotion of eco-labeling as a device to improve environmental performance should be exercised with caution.

2. A Model of Eco-Labeling

Consumers

The developing country (South) has a large number of consumers, N. The representative consumer is characterized by his preferences, and his disposable income I derived either from the ownership of productive input resources, or from direct production activities, net of any tax on income T.

Each consumer allocates his disposable income (I) between a *numéraire* commodity, y, which has no adverse environmental consequences, and a good x made in the developing country. The demand for x, $d_i^x (i = f, u)$, suitably subscripted, denotes the quantity of eco-friendly and eco-unfriendly products consumed by the representative consumer. More specifically, let the utility function of a representative consumer be

$$U(d_f^x, d_u^x, d^y) = \alpha \log D(d_f^x, d_u^x) + (1-\alpha)\log d^y.$$

$\alpha > 0$ denotes the weight allotted to the consumption of good x. In addition, $D(d_f^x, d_u^x)$ is a utility index which reflects consumers' taste for eco-friendly production methods,[2] with $D(d_f^x, d_u^x) = a_f d_f^x + a_u d_u^x$. In particular, $a_i > 0$ is a preference parameter that captures the private valuation of *one* unit of good d_i^x. Assume, in addition, that $a_f > a_u$ for all consumers. The interpretation of a_i depends on the particular commodity category in which eco-labeling is applied. For instance, in the case dolphin-safe tuna, the ratio $a \equiv a_f/a_u > 1$ (marginal rate of substitution) reflects consumers' willingness to exchange more than one unit of tuna produced via unsafe means for one unit of dolphin-safe tuna. Also let p_l (p_n) be the market price of a labeled (unlabeled) product.[3]

We use subscripts f and u to denote eco-friendly and eco-unfriendly products while the subscripts l and u refers to labeled and unlabeled products. In the present context with perfect enforcement, labeled products are synonymous with eco-friendly products while unlabeled products are synonymous with eco-unfriendly ones. By standard arguments (Dixit and Stiglitz, 1977), the utility-maximizing solution of the consumer's decision problem is given by the expenditure shares α and $1 - \alpha$, which consumers devote to the consumption of goods x and y, along with the two demand functions $d_i^x(p_l, p_n)$ $i = f, u$:

$$d_f^x(p_l, p_n) = \begin{cases} \dfrac{\alpha I}{p_l}, & \text{if } \dfrac{a_f}{p_l} > \dfrac{a_u}{p_n}; \\ 0 & \text{if } \dfrac{a_f}{p_l} < \dfrac{a_u}{p_n}, \end{cases} \tag{1}$$

$$d_u^x(p_l, p_n) = \begin{cases} \dfrac{\alpha I}{p_n}, & \text{if } \dfrac{a_f}{p_l} < \dfrac{a_u}{p_n}; \\ 0 & \text{if } \dfrac{a_f}{p_l} > \dfrac{a_u}{p_n}. \end{cases} \tag{2}$$

Thus, demand is positive for both labeled and unlabeled products if and only if

$$\frac{p_l}{p_n} = \frac{a_f}{a_u} > 1. \tag{3}$$

It follows, therefore, that the introduction of eco-labeling gives rise to consumption demand for both eco-friendly and eco-unfriendly products that are nondecreasing in income (equations (1) and (2)).[4] In addition, demand curves are negatively sloped as long as $d_i^x > 0$.

Northern consumers are assumed to have identical preferences as consumers in the South and hence the utility-maximization problem of a representative Northern consumer is identical to that of their Southern counterparts.

Production

The two sectors y and x constitute the production side of the developing country. Production of the composite *numéraire* y uses as input, a composite resource L_y, with $y = \beta L_y$, where $\beta > 0$ denotes both the average and the marginal productivity of the composite resource. The economy-wide return to the composite input resource is thus given by β.

A large number of producers, M, are engaged in the production of good x in the developing economy. Each individual producer is endowed with an equal amount of capital $\overline{K} > 0$ which can be invested in either the eco-friendly method of production of x or in the eco-unfriendly method. Production of either the eco-friendly or unfriendly product thus requires the use of two inputs: capital and the composite resource. To focus on the choice of production technique by producers, the production function of the eco-friendly product is given simply by

$$x_f = \min\left\{\overline{K}, \frac{\ell_f}{(1+b)}\right\},$$

where ℓ_f is the amount of resource input employed in the production of the eco-friendly product. $b > 0$ denotes a firm-specific technological parameter that captures the cost-effective eco-friendly production to which the producer has access. The production of the eco-unfriendly (unlabeled) product is

$$x_u = \min\{\overline{K}, \ell_u\}.$$

With $b > 0$, the specification of the production functions above requires that eco-friendly production entails higher resource costs. In addition, the technological parameter $b \in [\underline{b}, \infty]$ should be interpreted as a firm-specific production cost parameter: since unit cost, $\beta(1 + b)$, is strictly increasing in b, a higher b indicates a higher per-unit cost of eco-friendly production. The relative cost effectiveness of eco-friendly production among the M producers in the developing country is characterized by a cumulative distribution function $\mu(b, \gamma)$. $\mu(\cdot)$ is taken to be continuously differentiable over the relevant range with a strictly positive density function $\mu_b > 0$. In addition, a decrease in γ represents first-order stochastic dominance—a rightward shift of the cost distribution.

The decision problem of producers involves the choice between the two techniques of production to maximize profits at given prices, p_l and p_u, and at a given per-unit cost of applying an eco-label, k. Specifically, eco-friendly production is profit-maximizing if and only if

$$p_l\overline{K} - \beta(1+b)\overline{K} - k\overline{K} \geq p_u\overline{K} - \beta\overline{K} \Leftrightarrow b \leq \frac{p_l - p_u - k}{\beta}.$$

Thus, individual firms in the developing country self-select into two groups, according to their choice of production technique that is either eco-friendly or unfriendly. In particular, as long as eco-friendly and eco-unfriendly products coexist, we can define

$$\tilde{b}(p_l, p_u, \beta) \equiv \max\left\{\frac{p_l - p_u - k}{\beta}, \underline{b}\right\}. \tag{4}$$

It follows that if $b < \tilde{b}(p_l, p_u, \beta)$, or equivalently, if the price premium of labeled products is sufficiently higher than the associated costs, producers should optimally elect eco-friendly methods of production.[5]

The supply of the eco-friendly product is therefore $x_l = \mu(\tilde{b}, \gamma)M\overline{K}$ while that of the unlabeled product is $x_u = [1 - \mu(\tilde{b}, \gamma)]M\overline{K}$. Since μ is increasing in p_l and decreasing in p_n and β, (i) both eco-friendly and eco-unfriendly products have upwardly sloping (own-price) supply curves; (ii) an increase in wage cost β biases producer incentives away from eco-friendly methods, and (iii) a decrease in γ which shifts the distribution of production costs $\mu(b, \gamma)$ to the right has a similar adverse impact on the supply of eco-friendly products.

Also let $\pi(p_l, p_n, \gamma)$ denote aggregate producer profits in the production of x, where

$$\pi(p_l, p_n, \gamma) = p_l x_l + p_n x_u - \left[\int_{\underline{b}}^{\tilde{b}} (\beta(1+b)+k)d\mu(b,\gamma) + \int_{\tilde{b}}^{\infty} \beta d\mu(b,\gamma)\right] M\overline{K}.$$

By utilizing the definition of green premium, $p_l - p_n = p_n(a - 1)$, we have

$$\pi(p_l, p_n, \gamma) = \left[p_n(1+\mu(\tilde{b},\gamma)(a-1)) - \int_{\underline{b}}^{\tilde{b}} (\beta(1+b)+k)d\mu(b,\gamma) - \int_{\tilde{b}}^{\infty} \beta d\mu(b,\gamma)\right] M\overline{K}. \quad (5)$$

Thus, taking prices p_l and p_n as given, we have

$$\begin{aligned}\frac{\partial \pi(p_l, p_n, \gamma)}{\partial \tilde{b}} &= (p_n(a-1) - \beta(1+\tilde{b}) - k + \beta)\mu_b(\tilde{b},\gamma)M\overline{K} \\ &= (p_l - p_n - k - \beta\tilde{b})\mu_b(\tilde{b},\gamma)M\overline{K} = 0,\end{aligned}$$

where the last equality follows from (3). It follows, therefore, that since eco-labeling implies that relatively low-cost producers are favorably selected in the pool of eco-friendly producers, aggregate producer profits are maximized when the marginal firm has a cost parameter b that is given exactly by $\tilde{b}$. Note that the second-order condition is also satisfied, since $(\partial^2\pi/\partial\tilde{b}) = -\beta\mu_b < 0$.

To complete the characterization of the production side of the two-country world, we assume that the developed economy is specialized in the production of the composite commodity.[6] Let an asterisk (*) denote variables pertaining to the developed country and since $L_y^* = N^*e^*$, total Northern output of y is given as $y^* = \beta^*N^*e^*$.

General Equilibrium

We are now in a position to characterize the determination of the equilibrium prices for labeled and unlabeled products. Since the government recovers $k\mu(\tilde{b}, \gamma)M\overline{K}$ from the license fees collected from producers, government budget balance requires that lump-sum transfers to consumers ($-NT$) be equal to total receipts from license fees:

$$k\mu(\tilde{b},\gamma)M\overline{K} + NT = 0.$$

Thus, total disposable consumer expenditure (including income from resource ownership, producer profits, and lump-sum transfers) on labeled and unlabeled products in the two countries is equal to total revenue of producers of good x if

$$\alpha(\beta eN + \pi(p_l, p_n, \gamma) + k\mu(\tilde{b},\gamma)M\overline{K}) + \beta^*e^*N^* = p_n(1+\mu(\tilde{b},\gamma)(\alpha-1))M\overline{K}. \quad (6)$$

Note that by standard arguments, the market for the composite commodity clears, and can thus be ignored.

3. Market Responses to Eco-labeling under Perfect Monitoring

With the simple analytical setup discussed above,[7] we arrive at a number of conclusions regarding the role of eco-labeling in preventing environmental abuse.

Eco-labeling as a Market-Based Solution

To see that eco-labeling constitutes a market-based solution to the problem of under-consumption of eco-friendly products, note that if labeled and unlabeled products coexist, then from equation (3): (i) the price of labeled products strictly exceeds that of unlabeled products, and (ii) the relative price, p_l/p_n, reflects precisely consumers' relative willingness to pay for (the marginal rate of substitution between) eco-friendly and eco-unfriendly products. In particular, the marginal rate of substitution is defined as

$$\frac{\partial U/\partial d_f^x}{\partial U/\partial d_u^x} = \frac{a_f D(d_f^x, d_u^x)}{a_u D(d_f^x, d_u^x)} = \frac{a_f}{a_u} = \frac{p_l}{p_n},$$

where the last equality follows from equation (3). Thus, consumer's relative willingness to pay for eco-friendly products is equal to the relative market prices of the labeled and unlabeled products.

In contrast, absent labeling, consumers have no means of distinguishing between eco-friendly and eco-unfriendly products. As such, regardless of the production method undertaken by producers, a uniform price p prevails for products produced via either means. It follows, therefore, that the willingness of consumers to pay for eco-friendly products (the marginal rate of substitution, $a_f/a_u > 1$) is strictly greater than the prevailing market price of eco-friendly products relative to eco-unfriendly ones.

Indeed since $p_l - p_n = 0$ in the absence of labeling

$$\tilde{b} = \max\left\{\frac{p_l - p_n - k}{\beta}, \underline{b}\right\} = \underline{b}.$$

As should be expected, producers in this scenario fail to elect eco-friendly methods of production in the absence of a green premium since they have no means of internalizing the environmental consequences of their choice of production methods. To make the case for eco-labeling even stronger, it can be readily shown that self-selection among producers in response to eco-labeling guides production and consumption decisions in the two countries to their efficiency frontier. To see this, consider the problem of a planner whose objective is to maximize $U(d_f^x, d_u^x, d^y)$ by choice of consumption allocation between the two countries, $\{\hat{d}_i^x, \hat{d}_i^{x*}\}$, $i = f, u$, and $\{\hat{d}^y, \hat{d}^{y*}\}$ and the allocation of producers in the developing country between eco-friendly and eco-unfriendly production processes, $\hat{b}$; subject to the following constraints:

$$d_f^x + d_f^{x*} \leq \mu(\tilde{b},\gamma)M\overline{K}, \tag{7}$$

$$d_u^x + d_u^{x*} \leq (1-\mu(\tilde{b},\gamma))M\overline{K}, \tag{8}$$

$$d^y + d^{y*} \leq y + y^* = \beta e N + \beta^* e^* N^* - \left(\int_{\underline{b}}^{\tilde{b}} (\beta(1+b)+k)d\mu(b,\gamma) + \int_{\tilde{b}}^{\infty} \beta d\mu(b,\gamma)\right)M\overline{K}, \tag{9}$$

$$U(d_f^{x*}, d_u^{x*}, d^{y*}) \geq \overline{U}^*. \tag{10}$$

Maximizing $U(d_f^x, d_u^x, d^y)$ subject to expressions (7)–(10) yields the familiar conditions on consumption allocations:

$$\frac{\partial U/\partial d_f^x}{\partial U/\partial d_u^x} = \frac{\partial U^*/\partial d_f^{x*}}{\partial U^*/\partial d_u^{x*}}, \frac{\partial U/\partial d_f^x}{\partial U/\partial d^y} = \frac{\partial U^*/\partial d_f^{x*}}{\partial U^*/\partial d^{y*}},$$

which may be achieved, under decentralization, via free trade between the developed and developing countries. In addition, ruling out cases in which a is sufficiently small, so that $\tilde{b}$ is an interior solution, efficient allocation of producers in the developing country, $(\hat{b})$, requires that

$$\frac{1}{\beta}\left[\left(\frac{\alpha}{1-\alpha}\right)\frac{\hat{d}^{y}}{D(\hat{d}_f^x,\hat{d}_u^x)}(a_f-a_u)-k\right]=\frac{1}{\beta}\left[\left(\frac{\alpha}{1-\alpha}\right)\frac{\hat{d}^{y*}}{D(\hat{d}_f^{x*},\hat{d}_u^{x*})}(a_f-a_u)-k\right]=\hat{b}.$$

To confirm that $\hat{b}$ indeed coincides with $\tilde{b}$ in equation (4), note that

$$\left(\frac{\alpha}{1-\alpha}\right)\frac{d^{y}}{D(d_f^x,d_u^x)}(a_f-a_u)=\left(\frac{\alpha}{1-\alpha}\right)\left(\frac{(1-\alpha)I}{\alpha I a_u/p_n}\right)(a_f-a_u)=p_l-p_n,$$

where the second equality follows from equation (3), since

$$D(d_f^x,d_u^x)=a_f d_f^x+a_u d_u^x=a_f d_f^x+a_u\left(\frac{\alpha I}{p_n}-\frac{p_f d_f^x}{p_n}\right)=\frac{\alpha I a_u}{p_n}.$$

Thus, $\tilde{b}=\hat{b}$. The intuition as to why eco-labeling, under perfect monitoring, allows countries to reach their efficiency frontier lies in the observation that the absence of labeling gives rise to a consumption distortion as the relative price of eco-friendly products is strictly less than the consumers' relative valuation of eco-friendly products (the marginal rate of substitution between eco-friendly and eco-unfriendly products). The introduction of labeling corrects this distortion by allowing for a positive green premium that enables countries to reach their efficiency frontiers.

Environmental Consequences of Economic Growth

As a first link between the use of eco-labeling and the oft-noted growth–environment tradeoff, note from equation (6), along with the definition of $\tilde{b}$ in equation (4), that

$$\begin{aligned}&\frac{\partial p_n}{\partial e^*}=\frac{\alpha N^*\beta^*}{\Delta}>0,\quad \frac{\partial p_l}{\partial e^*}=a\frac{\partial p_n}{\partial e^*}>\frac{\partial p_n}{\partial e^*},\\ &\frac{\partial\tilde{b}}{\partial e^*}=\frac{(a-1)}{\beta}\frac{\partial(p_l-p_n)}{\partial e^*}>0,\end{aligned}\tag{11}$$

where $\Delta=(1-\alpha)(x_u+ax_l)+[(p_n(a-1)-\alpha k)/\beta]\mu_b(\tilde{b},\gamma)(a-1)M\overline{K}>0$, since $p_n(a-1)-\alpha k>p_n(a-1)-k=\tilde{b}\geq 0$. Likewise, similar manipulations yield

$$\frac{\partial\tilde{b}}{\partial e}=\frac{(a-1)\alpha N\beta}{\Delta}>0.$$

Thus, growth-driven increase in aggregate demand, originating either from the developed or the developing country, raises the market price of labeled products by proportionately more than that of unlabeled products. Also, the widening gap between the price of eco-friendly and eco-unfriendly products, in turn, translates to a larger equilibrium fraction of producers in the developing country who employ eco-friendly production methods, since $(p_l-p_n-k)/\beta=\tilde{b}$.

In particular, define $\varepsilon=-d\log(1-\mu(\tilde{b},\gamma))/d\log(p_l-p_n)$ as the elasticity of supply of the eco-unfriendly output with respect to the green premium. It follows that if and only if $\varepsilon>1$:

$$\frac{\partial p_n(1-\mu(\tilde{b},\gamma))}{\partial e}<0\Leftrightarrow 1-\mu(\tilde{b})-\frac{p_n}{\beta}\mu_b(\tilde{b},\gamma)(a-1)=(1-\mu(\tilde{b},\gamma))(1-\varepsilon)<0;$$

and hence, *eco-unfriendly products are inferior goods in general equilibrium in the presence of eco-labeling*, in the sense that consumer income $p_n(1 - \mu(\tilde{b}, \gamma))K\overline{M}$ spent on eco-unfriendly products *declines* during the process of economic growth. The intuition as to why eco-unfriendly products are inferior goods in general equilibrium can be seen from the fact that the institution of eco-labeling leads to a relatively higher increase in the price of the labeled products (since consumers' valuation of eco-labeled products is higher). The green-premium thus generated makes the production of eco-friendly products relatively more attractive to the producers. The ensuing increase in the supply of eco-friendly products ensures that the market-clearing output of eco-unfriendly products is lower than without eco-labeling.

In contrast, the absence of eco-labeling implies that consumers' private valuation for environmentally friendly products fails to be reflected in market prices. As such, a growth-driven increase in consumer demand has precisely the opposite impact, as rising consumer income implies a similar increase in consumer spending on eco-unfriendly products as consumers fail to distinguish between eco-friendly and eco-unfriendly products. The absence of a green premium further dissuades producers from undertaking eco-friendly production which translates into an increase in the supply of eco-unfriendly products.[8] It follows, therefore, that *eco-unfriendly products are normal goods in general equilibrium in the absence of labeling.*

Environmental Consequences of International Trade

By similar arguments, international trade with the developed country leads not only to traditional gains from trade via terms-of-trade improvements, but also an increase in demand originating from developed nations has environmental impacts that are similar to indigenous economic growth. In particular, international trade in the presence of eco-labeling has a pro-environment bias, precisely as producers in the developing country respond to the widening gap between the international price of labeled and unlabeled products by switching towards eco-friendly production methods.

The proof of this result is obtained from equation (11) above. With eco-labeling, the price of eco-friendly and eco-unfriendly products in the developing country in the *absence* of international trade, p_l^a and p_n^a, are given by

$$\alpha(\beta e N + \pi(p_l^a, p_n^a, \gamma) + k\mu(\tilde{b}, \gamma)M\overline{K}) = p_n^a\left[1 + \mu\left(\frac{p_l^a - p_n^a - k}{\beta}, \gamma\right)(a-1)\right]M\overline{K},$$
$$p_l^a = \frac{a_f}{a_u} p_n^a.$$

Clearly, $p_i^a < p_i$, $i = l, n$, and $p_l^a - p_n^a < p_l - p_n$ from equation (11), since the green premium, along with the individual prices p_l and p_n, are increasing in e^*. Put differently, commercial policies that restrict the flow of goods between the two countries and adversely affect consumer spending from the developed country on exports from the developing country also *decrease* the number of producers in the developing country who adopt eco-friendly production methods.

Environmental Consequences of Technological Change

We turn now to a characterization of how technologies interact with equilibrium investment in eco-friendly production, both via its direct effect on the cost of production, as well as its general equilibrium effect on the green premium. In particular, note that by definition, an increase in γ shifts the cost distribution to the left. Thus, $\mu_\gamma > 0$. In addition, we show in the Appendix that

$$\frac{\partial p_n}{\partial \gamma} = -\frac{\left[(p_n(a-1)-\alpha k)\mu_\gamma(\tilde{b},\gamma)(a-1)-\alpha\int_{\underline{b}}^{\tilde{b}}\beta\mu_\gamma(b,\gamma)db\right]M\overline{K}}{\Delta},$$

$$\frac{\partial \tilde{b}}{\partial \gamma} = \frac{a-1}{\beta}\frac{\partial p_n}{\partial \gamma},$$

$$\frac{\partial \mu(\tilde{b},\gamma)}{\partial \gamma} = \frac{\mu_b(\tilde{b},\gamma)(a-1)}{\beta}\frac{\partial p_n}{\partial \gamma} + \mu_\gamma(\tilde{b},\gamma)$$

$$= \frac{\left[(1+\mu(\tilde{b},\gamma)(a-1))(1-\alpha)\mu_\gamma(\tilde{b},\gamma)+\left(\alpha\mu_b(\tilde{b},\gamma)(a-1)\int_{\underline{b}}^{\tilde{b}}\mu_\gamma(b,\gamma)db\right)\right]M\overline{K}}{\Delta} > 0.$$

As should be expected, technological change that improves the overall cost-effectiveness of eco-friendly production raises the supply of eco-friendly products.

4. Enforcement and Monitoring under Imperfect Information

Key to the promise that eco-labeling holds for promotion of eco-friendly production methods is the ability on the part of consumers in differentiating between goods made with varying environmental consequences. Consequently, consumers' dis-utility of environmental abuse is reflected in markets through the price premium attached to the consumption of labeled products. Nevertheless, it is easy to see that the same price premium which encourages some producers to shift towards environmentally friendly production methods also has the potential of inducing others to apply eco-labels to mask their true (eco-unfriendly) production means. In particular, absent effective monitoring and enforcement of labeling standards, producers that apply false eco-labels can still capture the price premium that consumers are willing to pay, but at a cost that corresponds to eco-unfriendly production methods. In essence, the absence of effective enforcement and monitoring of producers opens up the possibility that consumers pay a price premium only to obtain an eco-unfriendly product.

The basic model developed above is therefore extended to account for the presence of imperfect and costly monitoring, along with the associated problem of false eco-labeling. In this context, a number of questions arise. First, to what extent can eco-labeling be expected to provide a solution to the problem of under-consumption of eco-friendly products via markets? Second, are there tradeoffs between economic progress and environmental conservation when the success of eco-labeling depends on effective policy intervention via the monitoring of eco-labels? In addition, what are the environmental consequences of international trade particularly when the decision-making of developing countries now involves the interplay between gains from trade and the costs of monitoring eco-labels?

Recall, therefore, our basic two-country setup, and consider (i) consumers who *rationally* account for the probability of consuming a labeled product produced via an eco-unfriendly method, along with (ii) producers who may falsely label depending on the intensity of monitoring. Let λ be the probability that a labeled product is eco-friendly. The analogue of equation (3), which relates the relative prices of labeled and unlabeled goods to consumers' willingness to pay, is simply

$$\frac{p_l}{p_n} = \frac{\lambda a_f + (1-\lambda)a_u}{a_u} = \lambda a + (1-\lambda) \le a \tag{12}$$

whenever $\lambda \le 1$. As should be expected, the presence of false labeling decreases the premium that consumers are willing to pay for labeled goods.

On the production side, let ϕ be the probability that false labeling is discovered by a monitoring agency and c the per-unit penalty, upon discovery, for applying false labels. Given that k is the per-unit license fee for a label, producers of eco-unfriendly products are better off by using false eco-labels if and only if their expected profit from false labeling exceeds that from producing unlabeled products, or

$$[(1-\phi)p_l + \phi p_n - \beta - k - \phi c]\overline{K} \ge [p_n - \beta]\overline{K} \Leftrightarrow p_l - p_n \ge \frac{k+\phi c}{1-\phi}. \tag{13}$$

Expression (13) is the *false-labeling* constraint. Thus, (i) the larger the price premium attached to labeled products, and (ii) the lower the monitoring intensity ϕ, the more likely that false labels prevail. On the other hand, the larger the license fee for a label (k) or the penalty for false labeling (c), the lower the likelihood of false labeling.

Expressions (12) and (13) imply that, in equilibrium, the marginal producer who is just indifferent between eco-friendly and eco-unfriendly production is given by

$$\overline{b} = \frac{p_l - p_n - k}{\beta} = \frac{\phi(k+c)}{\beta(1-\phi)}. \tag{14}$$

Simply put, imperfect enforcement implies that aggregate supply of eco-friendly products depends on the monitoring intensity ϕ and the penalty c, precisely as the price premium reflects consumers' rational expectation regarding the fraction of truly eco-friendly products in the pool of labeled exports from the developing country.

Thus, total supply of labeled products (whether eco-friendly or not) that are sold at price p_l is given by $x_l = [\mu(\overline{b}, \gamma)/\lambda]M\overline{K}$. Total supply of unlabeled products, inclusive of those that are caught as falsely labeled products, and therefore sold only at p_n, is given by $x_n = (1 - [\mu(\overline{b}, \gamma)/\lambda])M\overline{K}$. Aggregate producer profits are

$$\begin{aligned}\pi(p_l, p_n, \phi, \gamma) = p_l x_l - \left[k\mu(\overline{b}, \gamma) + (k+\phi c)\left(\frac{1/\lambda - 1}{1-\phi}\right)\mu(\overline{b}, \gamma) + \int_{\underline{b}}^{\overline{b}} \beta(1+b)d\mu(b, \gamma)\right]M\overline{K} \\ + p_n x_u - \int_{\overline{b}}^{\infty} \beta d\mu(b, \gamma)M\overline{K},\end{aligned}$$

where $k\mu(\overline{b}, \gamma)$ is the cost of applying a label for the true labelers while

$$(k+\phi c)\left(\frac{1/\lambda - 1}{1-\phi}\right)\mu(\overline{b}, \gamma)$$

is the cost of applying a label for the false labelers.[9] Note in addition, that since $p_n\lambda(a-1) = p_l - p_n = (k + \phi c)/(1 - \phi)$ from (13), we have

$$\begin{aligned}\pi(p_l, p_n, \phi, \gamma) = p_n(1 + \lambda\mu(\overline{b}, \gamma)(a-1))M\overline{K} \\ - \left[\int_{\underline{b}}^{\overline{b}} (\beta(1+b)+k)d\mu(b, \gamma) + \int_{\overline{b}}^{\infty} \beta d\mu(b, \gamma)\right]M\overline{K},\end{aligned} \tag{15}$$

where the equality follows from (12). Thus, in comparison to the case with perfect monitoring wherein aggregate profits are shown to be maximized via producer self-selection alone, aggregate profits and producer self-selection under imperfect monitoring can be affected, at constant prices p_l and p_n, through a change in the monitoring intensity:

$$\frac{\partial\pi(p_l,p_n,\phi,\gamma)}{\partial\phi}=\left[(p_n\lambda(a-1)-\beta(1+\bar{b})-k+\beta)\mu_\phi(\bar{b},\gamma)+p_n(a-1)\mu(\bar{b},\gamma)\frac{\partial\lambda}{\partial\phi}\right]M\bar{K}$$
$$=\frac{(k+c)}{(1-\phi)^2}\mu(\bar{b},\gamma)M\bar{K}>0, \quad (16)$$

where the last equality follows from the definition of $\bar{b}$ (equation (14)) and by substituting for $\lambda = (k + \phi c)/[p_n(a - 1)(1 - \phi)]$. Thus, as long as there exists some degree of false labeling $\lambda < 1$, aggregate producer profits can be increased by simply increasing the fraction of eco-friendly producers through an increase in the monitoring intensity. The result follows since each act of false labeling creates a negative externality on the other producers in the developing country, as consumers rationally account for the presence of a mixed pool of products with differing environmental consequences. As such, consumers' relative valuation for eco-friendly products $p_n(a - 1)$ is strictly greater than the increase in unit cost that the marginal firm $\bar{b}$ incurs ($p_l - p_n = p_n\lambda(a - 1)$) whenever $\lambda < 1$.

Finally, let the cost required to monitor eco-labeling programs, in units of the *numéraire*, be given by $\tau\phi$. Given that the government recovers

$$\left[k+(k+\phi c)\left(\frac{1/\lambda-1}{1-\phi}\right)\right]\mu(\bar{b},\gamma)M\bar{K}$$

from the penalty, it follows that the government budget constraint is

$$NT=\tau\phi-\left[k+(k+\phi c)\frac{(1/\lambda-1)}{(1-\phi)}\right]\mu(\bar{b},\gamma)M\bar{K},$$

where T gives the lump-sum tax levied on each one of the N consumers. It follows that the analogue of the market-clearing relationship in equation (6) is just

$$\alpha(\beta eN-NT+\pi(p_l,p_n,\phi,\gamma)+\beta^*e^*N^*)=p_n\left[1+\mu(\bar{b},\gamma)\frac{p_l-p_n}{\lambda p_n}\right]M\bar{K}$$
$$\Leftrightarrow\alpha\left\{\beta eN-\tau\phi+\left[k+(k+\phi c)\left(\frac{1/\lambda-1}{1-\phi}\right)\right]\mu(\bar{b},\gamma)M\bar{K}+\pi(p_l,p_n,\phi,\gamma)+\beta^*e^*N^*\right\}$$
$$=p_n(1+\mu(\bar{b},\gamma)(a-1))M\bar{K}. \quad (17)$$

Thus, increasing the intensity of monitoring efforts ϕ, raises the fraction of eco-friendly producers $\mu(\bar{b},\gamma) = \mu(\phi(k + c)/\beta(1 - \phi), \gamma)$, and puts downward pressure on the price p_n of eco-unfriendly products. Specifically:

$$\frac{\partial p_n}{\partial\phi}=-\frac{\tau\alpha+\left(p_n(a-1)(1-\alpha)+\dfrac{\phi(k+c)}{1-\phi}\right)\mu b(\bar{b},\gamma)M\bar{K})\dfrac{k+c}{\beta(1-\phi)^2}}{(1+\mu(\bar{b},\gamma)(a-1))(1-\alpha)M\bar{K}}<0. \quad (18)$$

Thus, there are two effects in play. First, raising monitoring intensities increases the fraction of eco-friendly producers, and diverts consumer income away from eco-unfriendly products. Meanwhile, since costly monitoring decreases consumer income via lump-sum taxation T, the negative impact of an increase in ϕ on p_n is further reinforced via this negative income effect.

5. Market Responses to Eco-labeling under Imperfect Monitoring

Eco-labeling as a Market-Based Solution

At this point, it should be apparent that the effectiveness of eco-labeling as a market-based solution to the problem of under-consumption of eco-friendly products is hampered in the presence of imperfect enforcement. In particular, so long as there is pooling of false eco-labels with products that are produced via eco-friendly methods, rational consumers discount their willingness to pay for labeled products. Consequently, as shown in expression (12), the relative market price of labeled goods *under-estimates* the utility gains on the part of consumers for eco-friendly products, with

$$\frac{p_l}{p_n} = a - (1-\lambda)(a-1) \le a.$$

Perhaps more importantly, the presence of imperfect information biases producers' incentives against the use of eco-friendly methods (as compared to the case of perfect monitoring) since the price premium can be captured, depending on monitoring intensity and the penalty, even when production is undertaken by means of eco-unfriendly methods and products are sold via false labeling. Specifically, as long as eco-friendly and eco-unfriendly products co-exist

$$\bar{b} = \frac{p_l - p_n - k}{\beta} = \frac{p_n\lambda(a-1) - k}{\beta}$$

is strictly decreasing in the share of false labels $1 - \lambda$. As a second round consequence of imperfect monitoring, therefore, producers of goods with false labels confer a *negative* externality on all producers of eco-friendly products, precisely since the prevalence of false labels drives consumers' valuation of labeled goods, eco-friendly or otherwise, downwards. Thus, comparing the definition of $\bar{b}$ above with $\tilde{b}$ which is on the efficiency frontier (equation (4)), it should be clear that Pareto optimality is no longer guaranteed.

Environmental Consequences of Economic Growth

In the absence of credible monitoring efforts, the relationship between economic growth and environmental abuse becomes much more complex. Specifically, unless monitoring intensity keeps pace with economic growth, an increase in aggregate demand can have no impact on the incentives of producers to switch in favor of eco-friendly means of production. In order to see why, first consider the market clearance condition

$$\alpha\left\{\beta e N - \tau\phi + \left[k + (k+\phi c)\left(\frac{1/\lambda - 1}{1-\phi}\right)\right]\mu(\bar{b},\gamma)M\bar{K} + \pi(p_l,\, p_n,\, \gamma,\, \phi) + \beta^* e^* N^*\right\}$$
$$= p_n\left[1 + \mu\left(\frac{\phi(k+c)}{\beta(1-\phi)},\, \gamma\right)(a-1)\right]M\bar{K}.$$

Clearly, as long as the monitoring intensity ϕ remains unchanged, total consumer expenditure on eco-unfriendly products

$$p_n\left[1 - \mu\left(\frac{\phi(k+c)}{\beta(1-\phi)},\, \gamma\right)\right]M\bar{K}$$

and on the labeled products (eco-friendly or not) is monotonically increasing in e and e^*. However, the price premium $p_l - p_n = (k + \phi c)/(1 - \phi)$, as determined by the false-labeling constraint (13), is independent of the growth-induced changes in aggregate demand and is determined solely by the monitoring intensity, license fee, and the penalty associated with false labeling. Therefore, the increases in p_l and p_n consequent upon an increase in income must be proportionate to one another in order to satisfy the false-labeling constraint.

Thus, an increase in consumer income, in the absence of increased monitoring, has the effect of increasing the supply of both unlabeled (eco-unfriendly) and labeled products. But does an increase in the supply of labeled products imply an increase in the supply of the eco-friendly products? From expressions (12) and (13) we have

$$p_l - p_n = p_n \lambda(a-1) \Leftrightarrow \lambda = \frac{k+\phi c}{1-\phi}\frac{a-1}{p_n}. \tag{19}$$

The fraction of true labels (λ) is thus inversely related to consumer income e^* and e, since p_n is strictly increasing respectively in e^* and e. It follows that the incidence of false labeling $(1 - \lambda)$ rises and falls with consumer income. Accordingly, an increase in the price of labeled products, consequent upon an increase in consumer income, has the effect of increasing the supply of false-labeled products as producers mask their true production methods, rather than switching in favor of eco-friendly ones. Meanwhile, consumer expenditure on products with false labels,[10]

$$p_l\left(\frac{1}{\lambda}-1\right)\mu(\bar{b},\gamma)M\bar{K} = \left(p_n + \frac{k+\phi c}{1-\phi}\right)\left(\frac{1-\lambda}{\lambda}\right)\mu(\bar{b},\gamma)M\bar{K}$$

also rises and falls with consumer income since $\partial p_n/\partial e > 0$ from equation (17). Thus, *eco-unfriendly (falsely labeled and unlabeled) products are normal goods in general equilibrium, when monitoring fails to keep pace with economic growth.* Contrary to the original intent of eco-labeling, therefore, economic progress under imperfect enforcement and information imperfection on the part of consumers is harmful to the environment.

A question that remains, however, is whether the monitoring intensity chosen optimally by the government of a developing country may respond to exogenous economic growth in a predictable fashion. In this context, consider a planner whose objective is to maximize the welfare of the developing country, taking into account the associated net cost of monitoring. The indirect utility of the developing economy is

$$V(\phi) = \log W + \alpha \log\left(\frac{a_u}{p_n}\right) + \log(\alpha)^{\alpha}(1-\alpha)^{1-a},$$

where W denotes gross national product of the developing country, with

$$W = \left\{\beta e N - \tau\phi + \left[k + (k+\phi c)\frac{(1/\lambda - 1)}{(1-\phi)}\right]\mu(\bar{b},\gamma)M\bar{K} + \pi(p_l, p_n, \phi, \gamma)\right\}.$$

Thus:

$$\frac{\partial V(\phi)}{\partial \phi} = \left[p_n(a-1) - \frac{\phi(k+c)}{1-\phi}\right]\frac{\mu_b(\bar{b},\gamma)}{\beta(1-\phi)^2}M\bar{K} - \tau + \frac{\alpha\beta^* e^* N^*}{p_n}\frac{\partial p_n}{\partial_\phi} \geq (<) 0.$$

Denoting η as the elasticity of p_n with respect to monitoring intensity $d\log p_n / d\log(1-\phi) > 0 \left(\frac{\partial p_n}{\partial \phi} < 0\right)$ above, we get

$$\frac{\partial V(\phi)}{\partial \phi} = \left[p_n(a-1) - \frac{\phi(k+c)}{1-\phi} \right] \frac{\mu_b(\bar{b},\gamma)}{\beta(1-\phi)^2} M\bar{K} - \tau - \alpha\beta^* e^* N^*(1-\phi)\eta \geq (<) 0. \qquad (20)$$

From equation (20), three effects determine whether credible monitoring should be in place. First, since the marginal cost of producing the eco-friendly product is $\beta\bar{b} = \phi(k + c)/(1 - \phi)$ from equation (14), $p_n(a - 1) - \phi(k + c)/(1 - \phi)$ represents the utility gains from an increase in monitoring intensity, and via an increase in the profits of Southern firms. Clearly, the higher the market valuation of a unit of eco-friendly products $p_n(a - 1)$, the higher will be the direct benefits of an increase in monitoring intensity. Second, τ is the marginal resource cost incurred in monitoring activities; hence, the lower is the marginal resource cost, the higher the gains from increased monitoring. Third, an increase in ϕ embodies a terms-of-trade effect that adversely affects the welfare of the exporting developing country as $\partial p_n/\partial\phi$ is negative from equation (18). Therefore, the smaller the value of η the higher the gains from increased monitoring.

Thus, we can show that there exists an inverted-U relationship between economic growth and consumer expenditure on eco-unfriendly products originating from the developing country. As shown in the Appendix, evaluating the change in welfare at $\phi = 0$

$$\left.\frac{\partial V(\phi)}{\partial \phi}\right|_{\phi=0} \geq 0 \Leftrightarrow W \geq \frac{\tau\beta}{\alpha\mu_b(\underline{b},\gamma)(k+c)(a-1)}\left(1+\frac{\alpha s^*}{1-\alpha}\right) \equiv \overline{W}, \qquad (21)$$

where $s^* = \beta^* e^* N^*/(W + \beta^* e N^*)$. Thus, $\overline{W}$ denotes the critical income threshold, such that whenever $W > \overline{W}$, the developing country is strictly better off devoting a positive amount of domestic resources to monitoring efforts. Therefore, economic growth *prior* to the realization of the income threshold can only raise consumer spending on the eco-unfriendly output, as ϕ and hence the fraction of eco-friendly producers $\mu(\bar{b}, \gamma)$ are both equal to zero. This gives the upward-sloping portion of the inverted-U.

Meanwhile, as income exceeds the critical income threshold, welfare of the developing country is strictly increasing with respect to the monitoring intensity and the developing country will be willing to devote a positive amount of resources to monitoring. In order to determine the downward-sloping portion of the inverted-U curve —decreasing consumption expenditure on eco-unfriendly products with respect to rising income—note that consumer expenditure on eco-unfriendly products is given simply by:

$$[p_n(1+\mu(\bar{b},\gamma)(a-1)) - p_l\mu(\bar{b},\gamma)]M\bar{K} = \left[p_n(a-1) - \left(\frac{k+\phi c}{1-\phi}\right)\right]\mu(\bar{b},\gamma)M\bar{K}. \qquad (22)$$

Thus, whether or not the right-hand side of the above equation is decreasing in the developing country income (e), depends on the effect of a change in e on (i) the price of the unlabeled products, p_n; (ii) the fraction of firms that choose to produce the eco-friendly product, $\mu(\bar{b}, \gamma)$; and (iii) the welfare optimal level of monitoring, $\bar{\phi}$.

First, note that the effect of a change in e on the welfare optimal level of monitoring $\partial\bar{\phi}/\partial e$ can be obtained from equation (20), with

$$\frac{\partial\bar{\phi}}{\partial e} = -\frac{\partial^2 V}{\partial\phi\partial e} \Big/ \frac{\partial^2 V}{\partial\phi^2}.$$

Thus, so long as the objective function $V(\phi)$ is strictly concave, with $\partial^2 V/\partial\phi^2 < 0$, the welfare optimal level of monitoring intensity is strictly increasing in e if and only if the numerator $\partial^2 V/\partial\phi\partial e$ is strictly positive. As can be readily confirmed using equation

(20), the marginal benefits of increasing monitoring intensity is strictly increasing in Southern consumer income ($\partial^2 V/\partial\phi\partial e > 0$), which implies accordingly that $\overline{\phi}$ is strictly increasing in e if and only if

$$\left[(a-1)M\overline{K}\frac{\partial p_n}{\partial e}\right]-\alpha\beta^* e^* N^*(1-\phi)\frac{\partial \eta}{\partial e}>0.$$

Two effects thus dictate whether economic growth encourages a strengthening of monitoring. First, since rising consumption demand via an economic growth in the developing country (e) implies a corresponding increase in the valuation for eco-friendly products $p_n(a-1)$ (equation (17)), the first term in square brackets in the equation above is strictly positive. Second, if the size of the terms-of-trade effect due to monitoring—as measured by the elasticity η—responds negatively to economic growth ($(\partial\eta/\partial e) < 0$), or is otherwise sufficiently small, the overall impact of economic growth on the marginal benefits of raising monitoring intensity is strictly positive.

These observations imply that the downward-sloping segment of the inverted-*U* shape relationship linking economic growth and the consumption of eco-unfriendly products is indeed possible. In particular, since p_n is strictly increasing in e from equation (17), and

$$\mu(\overline{b},\gamma)=\mu\left[\frac{\phi(k+c)}{\beta(1-\phi)},\gamma\right]$$

is increasing in the monitoring intensity ϕ, it can be readily verified that a sufficient condition for consumption expenditure on eco-unfriendly products to decline with economic growth (for the right-hand side of equation (22) to be declining in e) is that the elasticity of eco-unfriendly output supply $\varepsilon = -d\log(1-\mu)/d\log(p_l - p_n)$ be sufficiently large, so that the negative output effect of an increase in monitoring prompted by government response to economic growth dominates the tendency for the price of falsely labeled eco-unfriendly products to increase with growth.

Also of interest at this point is whether the threshold income level is susceptible to change, and should, therefore, be expected to differ across similarly poor developing countries, and across different kinds of environmental abuse. In terms of our model, note from equation (21) that $\overline{W}$ is strictly increasing in τ (decreasing in $\mu_b(\underline{b}, \gamma)$, and α). It follows that a decrease in the cost of monitoring, an increase in producer access to cost efficient production methods (an increase in $\mu_b(\underline{b}, \gamma)$), and an increase in the share of income devoted to good x all contribute to a *reduction* in the threshold level of income.

Environmental Consequences of International Trade

In a similar fashion, gains from trade that are not accompanied by an increase in monitoring efforts confer damages to the environment since producers only respond to the increase in world demand by means of false labeling, as $\mu(\overline{b}, \gamma) = \mu(\phi(k+c)/\beta(1-\phi), \gamma)$ is independent of e or e^*. Perhaps more interestingly, we find that the choice of monitoring intensity on the part of developing economies suffers from a problem that is typical of nonexcludable public goods. In particular, we find that even if consumers view eco-friendly products as private goods, developing countries lack incentives to pay for monitoring since the utility gains from costly monitoring efforts is shared between the developing exporter and the developed importer. In fact, note from equation (21) that $\overline{W}$ is strictly increasing in s^*. Thus, setting $s^* = 0$, which applies in the absence of trade, the developing country benefits from initiating monitoring efforts whenever

$$W \geq \frac{\tau\beta}{\alpha\mu_b(\underline{b},\gamma)(k+c)(a-1)} \equiv \overline{W}^a < \overline{W}.$$

In effect, international trade can shift the inverted-U curve to the right, and delay the turning point of the economic growth and environmental relationship. To see the intuition behind this result, it will be useful to recall from (21) that national welfare change in response to an increase in monitoring intensity ϕ depends on

$$\frac{\partial V(\phi)}{\partial \phi} = 0 \Leftrightarrow \left[p_n(a-1) - \frac{\phi(k+c)}{1-\phi}\right]\mu_b(\overline{b},\gamma)\frac{(k+c)}{\beta(1-\phi)^2}M\overline{K} - \tau + \frac{\alpha\beta^* e^* N^*}{p_n}\frac{\partial p_n}{\partial \phi} = 0.$$

In addition to the direct welfare benefits $(1-\alpha)\mu_b(\overline{b},\gamma)$, net of the costs associated with increased monitoring, economies open to trade also face a *negative* terms-of-trade effect since an increase in ϕ lowers the price of eco-unfriendly exports. Thus, that $\overline{W}^a$ is less than $\overline{W}$ can be attributed to the terms-of-trade losses that are associated with monitoring. In particular, the larger is the share of imports of the developed country in world consumption s^*, the larger the terms-of-trade impact.[11]

6. Conclusion

We have shown that if consumers view labeled products as private goods then labeling does help in altering the incentives of producers in developing countries to shift to eco-friendly methods of production. Indeed, we show that eco-labeling with perfect enforcement guides both consumers and producers to the efficiency frontier of the developed and developing economies. In addition, the endogenous price premium allows choice of production technologies to reflect consumers' relative preference for eco-friendly production, and as such, we find that eco-friendly products are normal goods in general equilibrium. Consequently, income gains achieved via international trade can only be beneficial to the environment.

However, by extending the basic setup to incorporate the more realistic scenario with costly enforcement, our findings suggest that wholesale promotion of eco-labeling to improve environmental performance should be exercised with caution. In particular, we show that unless monitoring efforts keep pace with indigenous economic growth, the presence of false labeling that goes unchecked in turn implies that eco-unfriendly products are normal goods in general equilibrium. Interestingly, the incentive for developing economies to credibly enforce national eco-labeling schemes has a threshold property. In particular, the income threshold varies endogenously with the developing economy's openness to trade, the cost-effectiveness of monitoring technologies, and the terms-of-trade effects.

Appendix

Market Responses to Technological Change under Perfect Enforcement

To derive the results displayed in section 3, note that total disposable consumption income in the South can be written as

$$I = \left[p_n(1+\mu(\tilde{b},\gamma)(a-1)) - \beta(1+\tilde{b}\mu(\tilde{b},\gamma)) + \int_{\underline{b}}^{\tilde{b}} \beta\mu(b,\gamma)db\right]M\overline{K} \tag{A1}$$

by integrating by parts. Thus, making use of market clearance in equation (6), routine differentiation yields

$$\frac{\partial p_n}{\partial \gamma} = -\frac{(p_n(a-1) - \alpha k)\mu_\gamma(\bar{b}, \gamma) - \alpha \int_{\underline{b}}^{\tilde{b}} \beta \mu_\gamma(b, \gamma) db) M\bar{K}}{\Delta} \tag{A2}$$

as in the text.

Market Responses to Economic Growth under Imperfect Enforcement

To arrive at the income threshold as shown in section 5, make use of (18) to obtain

$$\left.\frac{\partial p_n}{\partial \phi}\right|_{\phi=0} = -\frac{p_n \mu_b(\underline{b}, \gamma)(a-1)M\bar{K}(k+c)/\beta + \alpha\tau}{(1-\alpha)M\bar{K}}. \tag{A3}$$

In addition, from equation (20), we have

$$\left.\frac{\partial V(\phi)}{\partial \phi}\right|_{\phi=0} = p_n(a-1)\mu_b(\underline{b}, \gamma)(k+c)M\bar{K}/\beta - \tau + \frac{\alpha\beta^* e^* N^*}{p_n}\left.\frac{\partial p_n}{\partial \phi}\right|_{\phi=0}, \tag{A4}$$

since $\phi = 0$ in the absence of monitoring efforts, and in addition $p_n x_u = p_n M\bar{K} = \alpha W + \alpha\beta^* e^* N^*$. The income threshold $\bar{W}$ as in the text follows from substituting (A3) into (A4).

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Notes

1. See also Basu and Chau (1998) for a study on trade under asymmetric quality information with country-of-origin as signals for quality.
2. See Dixit and Stiglitz (1977) for a discussion of the use of similar utility indexes when product differentiation is of central concern.
3. Note that we assume here that all labeled products are of the eco-friendly variety. The possibility of false labeling will be considered later.
4. Without a full description of the production side of the economy, and the mechanism through which the two prices are determined in general equilibrium, that demand for both goods are increasing in income alone does not necessarily imply that both labeled and unlabeled products are *normal goods* in general equilibrium. We deal with this issue later.
5. Of course, if willingness to pay a is small, so that the green premium is too low to justify costs (k), we have $\tilde{b} = \underline{b}$, and the fraction of producers who apply eco-labels is equal to zero. Thus, whether an eco-labeling program is in place is a matter of indifference to both producers and consumers. In what follows, we assume that a is large enough, so that a positive fraction of producers employ eco-friendly production methods so long as consumers are allowed to make informed choices.
6. Alternatively, let the Armington assumption apply, so that consumers in the developed country perceive imports orginating from the developing country as imperfect substitutes for domestic outputs, as embodied in the production function y^*.
7. Note that market clearance in equation (6) determines the price of the eco-unfriendly (unlabeled) products. Accordingly, the price of labeled products can be had using equation (3). Finally, the fraction of producers in the developing country that elects to produce via eco-friendly means is given once the absolute price premium $p_l - p_n$, and hence $\tilde{b}$, is determined.
8. To see this, note that $\tilde{b} = \underline{b}$ and $p_n x_u = \alpha(\beta^* e^* N^* + \beta e N + \pi)$, where x_u is given simply by $M\overline{K}$.
9. In particular, since $\mu(\overline{b}, \gamma)M$ of the $\mu(\overline{b}, \gamma)(1/\lambda)M$ number of producers of labeled products offer eco-friendly products, the total number of labelers who are nevertheless eco-unfriendly is simply $\mu(\overline{b}, \gamma)(1/\lambda - 1)M\overline{K}$. In addition, since $1 - \phi$ is the fraction of eco-unfriendly producers of labeled products remain undetected, the total number of false labelers must be equal to $\mu(\overline{b}, \gamma)(1/\lambda - 1)M/(1 - \phi)$, and accordingly, the total number of false labelers who are caught is given by $\phi\mu(\overline{b}, \gamma)(1/\lambda - 1)M/(1 - \phi)$.
10. Note that since λ is the fraction of eco-unfriendly outputs in the pool of labeled products, and $\mu(\overline{b}, \gamma)M\overline{K}$ is the total supply of eco-friendly products, $[(1 - \lambda)/\lambda]\mu(\overline{b}, \gamma)$ thus represents the total supply of falsely labeled products.
11. Basu and Chau (2001) show that when the developing and the developed country strategically compete in eco-labeling standards, then the lack of eco-labeling has a pro-trade bias while market access rivalry in the presence of eco-labeling exhibits a tariff-like outcome, with net exporters supplying too much eco-friendly products while net importers supplying too little.