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Envirodevonomics: A Research Agenda for an Emerging Field[†]

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Environmental quality in many developing countries is poor and generates substantial health and productivity costs. However, the few existing measures of marginal willingness to pay (MWTP) for environmental quality improvements indicate low valuations by affected households. This paper argues that this seeming paradox is the central puzzle at the intersection of environmental and development economics: Given poor environmental quality and high health burdens in developing countries, why is MWTP seemingly so low? We develop a conceptual framework for understanding this puzzle and propose four potential explanations for why environmental quality is so poor: (1) due to low income levels, individuals value increases in income more than marginal improvements in environmental quality; (2) the marginal costs of environmental quality improvements are high; (3) political economy factors undermine efficient policymaking; and (4) market failures such as weak property rights and missing capital markets distort MWTP for environmental quality. We review the literature on each explanation and discuss how the framework applies to climate change, which is perhaps the most important issue at the intersection of environment and development economics. The paper concludes with a list of promising and unanswered research questions for the emerging sub-field of "envirodevonomics."
(*JEL* I15, O10, O44, Q50)

1. *Introduction*

Most visitors to developing country cities notice the poor environmental quality: their eyes sting, the water makes them sick, the views are obscured by smog. These casual observations are backed up by the data. Figure 1 shows air and water quality in developed and developing countries. The top panel shows airborne particulate matter (PM_{10}) concentrations in urban centers, while the bottom panel shows dissolved oxygen, a measure of good water quality.[1]

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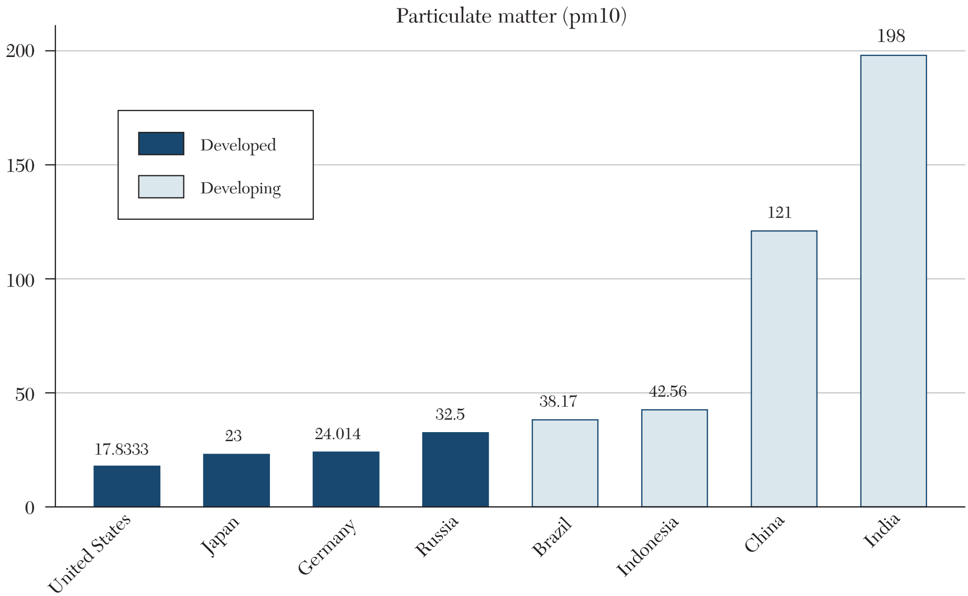
[1]Particulate matter comes both from primary sources (incomplete combustion, dust) and secondary reactions in the atmosphere. Particles smaller than ten micrometers in diameter are typically associated with the greatest risk to human health. Dissolved oxygen is a proxy for organic waste, which uses oxygen in decomposition, in the water. Sources of organic waste include sewage and urban runoff (US EPA).

Panel A. Air pollution



Panel B. Water pollution

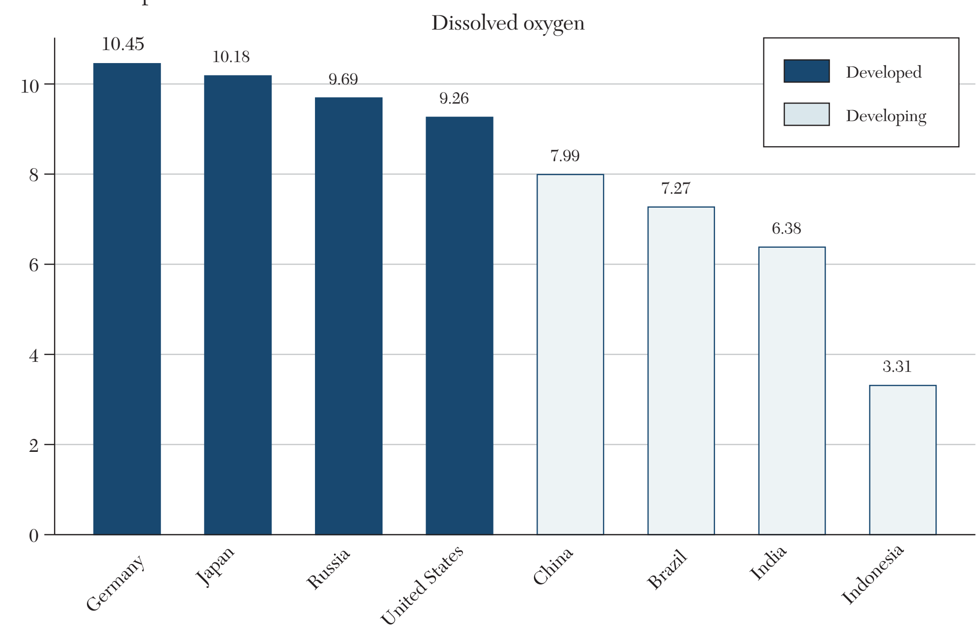


Figure 1. Environmental Quality in Developed and Developing Countries

Notes: Panel A shows average particulate matter (PM_{10}) from urban centers, in $\mu g/m^3$, using data from the World Health Organization (2011). Panel B shows dissolved oxygen, in mls/litre, using data from the United Nations Environment Program (2001). The four most populous developed and developing countries are shown, ranked according to the pollution measure (from least to most polluted).

The developing countries are remarkably dirtier (higher particulates, lower dissolved oxygen).[2]

These stark differences in environmental quality appear to have paradoxical consequences. On the one hand, the available evidence suggests that they lead to large health and productivity losses. For example, figure 2 shows the striking differences in the burden of disease from air and water pollution in developed and developing countries, as calculated by the World Health Organization.[3] On the other hand, in spite of this large disease burden, the small handful of studies measuring marginal willingness to pay (MWTP) for environmental quality improvements indicate low valuations by affected households. For example, using households' willingness to pay for access to clean water in Kenya to impute the value of a statistical life (VSL) leads to an estimate of USD2013 860 (Kremer et al. 2011), while typical VSL numbers from the United States are on the order of USD2013 8.6 million (U.S. EPA 2010).[4]

These seemingly contradictory facts raise a series of compelling questions and puzzles. Given poor environmental quality and high health burdens in developing countries, why is MWTP for environmental quality seemingly so low? Put another way, is the value of a life in Kenya, as suggested by the revealed preference data, really 10,000 times lower than typical figures for the value of a statistical life in the United States? Is the current level of environmental quality in developing countries optimal, leaving no room for policy improvements (i.e., is poor environmental quality just another dimension of poverty)? Is it possible that the welfare loss from poor environmental quality in developed countries is greater than in developing countries in spite of the substantially cleaner conditions in the former?

This paper argues that a series of critical economic and policy questions about environmental quality in developing countries cannot be properly analyzed or understood with the tools of environmental economics alone or the tools of development economics alone. We believe that research is increasingly producing credible answers to these questions and a new field is emerging that is at the intersection of these two larger and more well-established fields.[5] At the risk of excessive reductionism, we argue that this field can be organized around a central question: Why is environmental quality so poor in developing countries?

This paper develops four potential explanations for the poor state of environmental quality in developing countries that apply in varying degrees across contexts. These four explanations go beyond the traditional market failures associated with the public goods and externality characteristics of environmental quality and are likely to be especially important in developing countries. First and most obviously, environmental quality may be low because MWTP for environmental quality is low. There are several possible causes of seemingly low MWTP for environmental

[2] We follow the UN categorization of developed and developing countries (UN Statistics Division), though the binary country-level classification overlooks large variations both within category and within country.

[3] Obtaining causal estimates of the health consequences of environmental quality is challenging. Randomized control trials are unethical in many settings, and quasi-experiments face limitations when it comes to long-run impacts. In this paper, beginning in section 3, we emphasize the findings from experimental and quasi-experimental studies that we believe provide the most reliable causal estimates of the health impacts of pollution in developing countries.

[4] As the conceptual framework makes explicit, MWTP for environmental quality includes not only the valuation of morbidity and mortality benefits of improved environmental quality, but also aesthetic and income benefits.

[5] In many respects, this research is an answer to Horowitz's call for increased credibility in empirical research at the intersection of development and environmental economics in his review of the Dasgupta and Mäler (1997) edited volume *The Environment and Emerging Development Issues* (Horowitz 1998).

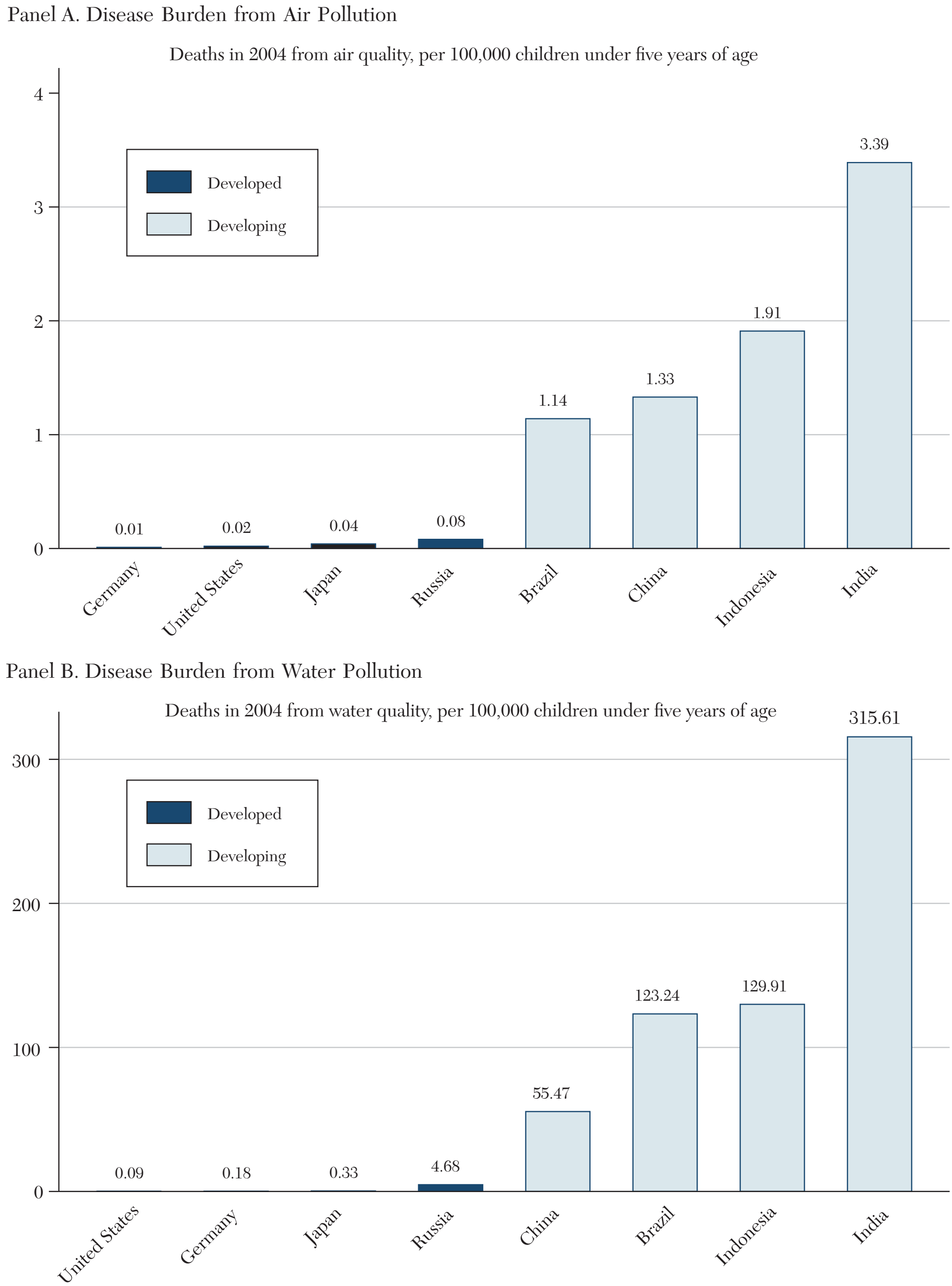


Figure 2. Burden of Diseases in Developed and Developing Countries

Notes: Panel A shows the burden of disease in deaths among children under five per 100,000 from outdoor air pollution. Panel B shows the burden of disease in deaths among children under five per 100,000 from poor water quality, sanitation, and hygiene. Data are from the World Health Organization (2004) for the four most populous developed and developing countries.

quality, including—most centrally—high marginal utility of consumption at low income levels. In other words, under a very tight budget constraint, individuals may prefer to spend what money they have on consumption than on investments in environmental quality. Second, high marginal costs of environmental quality improvements would also result in a lack of regulation to address issues like pollution or deforestation. Marginal costs are likely to be higher where policy design, implementation, and enforcement is weak. Third, the political economy of policy making in developing countries may distort the policy process. Poor environmental quality could then be explained by policymakers who do not implement the preferences of their constituents or implement the preferences of a subset of constituents at the expense of the majority. Fourth, MWTP for environmental quality may be distorted by market failures, including both the classic market failures of public goods and externalities, and also the market imperfections more common to developed countries: missing land, capital, and labor markets. Among other distortions caused by these market failures, missing credit markets lead to revealed preference measures that reflect liquidity constraints, rather than willingness to pay.[6]

The remainder of the paper is laid out as follows. The next section presents a simple conceptual framework for understanding why environmental quality is so poor in developing countries. Section 3 selectively reviews the existing empirical evidence on the health and productivity consequences of poor environmental quality. It also discusses the evidence on the four potential explanations for the poor environmental quality in developing countries described in the previous paragraph. While there is an extensive literature that dates back several decades that provides a crucial foundation for this field,[7] space constraints mean that we are only able to focus our attention on a relatively small set of papers that prioritize causal inference and/or open new areas of inquiry (and even with this constrained set our coverage is necessarily incomplete). Naturally, some will disagree with our choices, but the literature is too large to provide a complete treatment.

Four important trends emerge from this review that highlight the opportunity for, and urgency of, future research: the recognition of the substantial threats to well-being posed by poor environmental quality, improved modeling of behavior, the increasing availability of data in developing countries, and the recognition of surprisingly frequent opportunities for quasi-experimental and experimental estimation of key parameters. This confluence of trends provides ample fuel for the development of a rich and nuanced field where a combination of theory and empirics can produce economic insights with the potential to greatly increase social welfare.

Finally, section 4 focuses on climate change as a central pressing and policy-relevant issue at the forefront of environmental and development economics. It is in many ways the ultimate research topic, as it poses an existential threat to human well-being and encompasses all of the explanations for poor environmental quality in developing countries. Section 5 concludes by highlighting key areas for further theoretical and empirical research.

[6] Environmental quality is affected by the decisions of both individuals and policy makers. The first, second, and fourth of these explanations affect individual preferences and choices directly, as well as in the aggregate. The third explanation directly affects the actions of policy makers, which may in turn change individual decisions in response to a distorted policy environment.

[7] For recent reviews, see Dasgupta (2010), Barbier (2007), and the Summer 2010 issue of the *Review of Environmental Economics and Policy.*

2. *Why is Environmental Quality so Poor in Developing Countries?*

This section lays out a conceptual framework for understanding the causes of poor environmental quality in developing countries. We first consider a representative agent with utility from consumption, environmental quality, and health. The social planner aggregates agent preferences and maximizes net benefits by setting social marginal WTP for environmental quality equal to the marginal costs of providing it. Our starting point is a simple one-period model with no market failures that highlights issues that are likely to be highly salient in developing countries, but less relevant in developed countries.

We explore four explanations for poor environmental quality in developing countries: (1) the marginal utility of consumption is higher than the marginal utility of environmental quality improvements, (2) the marginal costs of environmental quality improvements are high, (3) political economy distorts the social planner's optimization problem, and (4) market failures cause measured MWTP for environmental quality to diverge from valuations in the first best. Note that the first two of these explanations require no deviation from unconstrained social welfare maximization, while the second two assume some additional constraints on optimization. These explanations are not mutually exclusive, but any one is sufficient to explain the observed poor environmental quality in developing countries.

The section closes by briefly reviewing the consequences of the market failures associated with the public good and/or externality characteristics of many forms of environmental quality. These market failures are likely to be equally present in developing and developed countries, so they are given limited attention here.

2.1 *Conceptual Framework*

In a simple, single-period static model, we consider an economy with n identical agents. Each of the agents is endowed with initial wealth y_0 and exogenously determined environmental quality e_0. Here, we assume that all markets function perfectly (i.e., no public goods or externalities) to benchmark first-best outcomes. For simplicity, we focus on one of these agents (i.e., the representative agent) who chooses consumption c, improvements in environmental quality Δe, and a level of self protection s to maximize utility:

$$u(e, h(s, e), c) \tag{1}$$

subject to the budget constraint

$$y \geq c_e(\Delta e) + c_s(s) + c, \tag{2}$$

where total wealth (endowment plus income) and the agent's experienced environmental quality are defined by

$$y = y_0 + \Delta y(e, h(s, e)) \tag{3}$$

$$e = e_0 + \Delta e + a(c, s). \tag{4}$$

The function $a(c, s)$ captures the impact of consumption and self protection on environmental quality as experienced by the agent, and $h(s, e)$ reflects the agent's health, which depends on self-protection and experienced environmental quality.

This utility function highlights a number of channels that affect preferences for environmental quality. First, environmental quality affects utility directly through, for example, aesthetic preferences or existence values. Second, environmental quality affects utility indirectly via health (which in turn affects income), $h(s, e)$. For example, workers exposed to high levels of pollution may be less productive. The effect of environmental quality on health can be mitigated through spending on self protection, s, such as indoor air purifiers or water treatment. Finally, environmental quality affects income (equation 3), which in turn affects utility via the budget constraint. Tourism revenue from a national park or agricultural income that is sensitive to water quality or the presence of pollinators are examples of environment-dependent income.

In addition, by allowing consumption to affect experienced environmental quality (equation 4), the model acknowledges that agents may affect environmental quality both directly, through Δe, and indirectly, through c and s. We model the latter as $a(c, s)$ to highlight consumption geared toward self-protection, such as air conditioning or bottled water, that creates feedbacks between self-protection, health, and environmental quality. Note that in this perfect markets set up, environmental quality is affected only by the agent's own choices, and does not include the environmental quality, consumption, or self protection choices of others.

The agent chooses c, Δe, and s to equalize the marginal utility of these investments. Let λ_e be the marginal utility of environmental quality improvements and λ_y be the marginal utility of consumption. Individual marginal willingness to pay is therefore the marginal rate of substitution between income and environmental quality.

$$(5) \quad MWTP_e \equiv \frac{\lambda_e}{\lambda_y} \equiv \frac{1}{\lambda_y}\left(\frac{\partial u}{\partial e} + \frac{\partial u}{\partial h}\frac{\partial h}{\partial e}\right) + \frac{\partial \Delta y}{\partial e} + \frac{\partial \Delta y}{\partial h}\frac{\partial h}{\partial e}.$$

This marginal WTP function expresses in dollars how much the agent will be willing to pay for a marginal increase in environmental quality. $MWTP_e$ is composed of the aesthetic benefit from improved environmental quality (scaled by the marginal utility of consumption) and the indirect benefit of environmental quality for health (again scaled by the marginal utility of consumption), as well as the impact of environment on income and the indirect impact of environmental quality on income via the changes in health.[8] Equation (5) makes clear that if utility is concave in consumption, low levels of income will correspond to high marginal utility of income (λ_y) and low $MWTP_e$.[9]

Similarly, we can calculate marginal WTP for self-protection s:

$$(6) \quad MWTP_s \equiv \frac{1}{\lambda_y}\left(\frac{\partial u}{\partial e}\frac{\partial a}{\partial s} + \frac{\partial u}{\partial h}\left(\frac{\partial h}{\partial s} + \frac{\partial h}{\partial e}\frac{\partial a}{\partial s}\right)\right) + \frac{\partial \Delta y}{\partial e}\frac{\partial a}{\partial s} + \frac{\partial \Delta y}{\partial h}\left(\frac{\partial h}{\partial s} + \frac{\partial h}{\partial e}\frac{\partial a}{\partial s}\right).$$

The MWTP for self-protection is composed of the indirect effect of self-protection on environmental quality and on health, both of which are scaled by the marginal utility of consumption, as well as its indirect effect on income via production and health. If the marginal utility of consumption is decreasing, then $MWTP_s$ is higher at higher levels of consumption, as long as any negative impacts of self-protection on environmental quality can be offset by compensatory investment in self-protection (in other words, the second of these indirect effects can be used

[8] A large literature investigates the hypothesis that there is an inverted-U shaped relationship between income and environmental quality—the so-called environmental Kuznets curve (e.g., Grossman and Krueger 1995; Andreoni and Levinson 2001; for reviews of the literature, see Dasgupta et al. 2002; Stern 2004). A number of potential explanations underlie the proposed relationship, including ones consistent with the micro model we present here. The macro relationship does not, however, appear robust across pollutants or time (Harbaugh et al. 2002).

[9] Note that λ_y also captures the indirect effects of consumption via environmental quality and its effect on production and health. $\lambda_y = \dfrac{\frac{\partial u}{\partial c} + \left(\frac{\partial u}{\partial e} + \frac{\partial u}{\partial h}\frac{\partial h}{\partial e}\right)\frac{\partial a}{\partial c}}{1 - \left(\frac{\partial \Delta y}{\partial e} + \frac{\partial \Delta y}{\partial h}\frac{\partial h}{\partial e}\right)\frac{\partial a}{\partial c}}$, which collapses to $\lambda_y = \frac{\partial u}{\partial c}$ if $\frac{\partial a}{\partial c} = 0$.

to offset the first). Thus, agents will prefer a higher income with greater investment in self-protection even if self-protection has a negative impact on environmental quality.

The marginal cost of improving environmental quality is $\frac{\partial c_e}{\partial \Delta e}$ and the marginal cost of self protection is $\frac{\partial c_s}{\partial \Delta s}$. The representative agent will therefore set the marginal costs of environmental quality improvements and of self protection equal to their respective marginal *WTP* (as defined in equations 5 and 6), such that the ratios are equal to each other:

$$(7) \qquad \frac{MWTP_e}{MWTP_s} = \frac{\frac{\partial c_e}{\partial \Delta e}}{\frac{\partial c_s}{\partial \Delta s}}.$$

With this set-up, individuals' decisions about c, Δe, and s will produce the first-best or socially efficient outcomes.

Even in this setting, it is instructive to introduce a social planner whose job it is to choose the level of environmental quality. For the social planner to achieve the socially efficient outcome by aggregating across the agents, it is necessary to assume that she has a costless technology to raise revenue, has no preferences of her own, and is able to observe true $MWTP_e$. The next subsection considers reasons that environmental quality is so poor in developing countries, with three of the explanations relying on violations of these assumptions. We postpone modeling the consequences of the classic externality and public goods characteristics of environmental quality until section 2.3.

2.2 *Four Explanations for Poor Environmental Quality in Developing Countries*

2.2.1 *Explanation 1: High Marginal Utility of Consumption*

We begin with the straightforward explanation that $MWTP_e$ is low because people in developing countries are poor, and therefore the marginal utility of consumption is high relative to the marginal utility of environmental quality. To put it simply: when people are very poor, what little money they have goes toward immediate consumption needs.

The comparative statics of our framework illustrate this point. The agent trades off consumption and environmental quality by setting the marginal utility of environmental quality equal to the marginal utility of consumption. If the marginal utility of consumption is decreasing, then the agent is likely to forego investments in environmental quality in favor of consumption at low levels. As the budget constraint is relaxed, the value of an additional unit of consumption falls and the trade-off between consumption and environmental quality becomes less extreme, increasing demand for the latter. For example, even if improvements in environmental quality lead to large, measurable health gains that improve the quality of life, these improvements may still be small relative to the utility gains (also possibly through improved health) from an increase in consumption. This explanation does not result from any market failure and suggests that the low levels of environmental quality in developing countries are socially efficient.

Richer models provide related explanations for poor environmental quality in developing countries. Consider an extension of the simple model above to one with two periods. If the probability of living to the next period in time is affected by environmental quality or health, then $MWTP_e$ will increase with income. Because later-period consumption is increasing in income and the marginal utility of consumption is decreasing, $MWTP_e$ will increase as income increases. Hall and Jones (2007) show that this holds for health spending, and the intuition extends to any good that increases the probability of living to the next period, provided that utility is additively separable over time. It is important to note that for many poor households, myriad risks affect the probability of living to the next period, which may increase the marginal utility of immediate consumption and further lower investment in environmental quality.

2.2.2 *Explanation 2: High Marginal Costs*

Without departing from an assumption of efficient markets, high marginal costs of providing environmental quality can explain the observed poor quality in developing countries. Specifically, high marginal costs of environmental quality improvements (Δe) can make such improvements socially inefficient (recall equation 7). Intuition suggests that increasing marginal costs of abatement would imply lower marginal costs of environmental quality improvements in settings with few existing regulations and high levels of pollution. However, marginal costs of environmental quality improvement may not be driven by abatement costs alone; they also reflect local capacity for policy design and implementation. In settings where capacity is weak, the marginal cost of environmental quality improvement may be high even if marginal abatement costs are relatively low.

Weak capacity in other policy domains may also increase the cost of environmental quality improvements. Specifically, if policymakers lack the means to collect tax revenue efficiently, then the very process of collecting revenues for environmental quality investments may be costly. Alternatively, low marginal costs of self-protection may lead individuals or policy makers to prefer investments in self-protection to improvements in environmental quality.

Other investments in the economy can affect the marginal cost of environmental quality improvements. For example, regulatory costs are likely decreasing in the infrastructure associated with monitoring the production process. Relative to developed countries, many of these complementary investments in infrastructure are absent or nascent, resulting in higher marginal costs of environmental quality improvements. Changes in regulation or the centralized provision of environmental quality also affect the privately optimal investment choice of individuals or firms, which may enhance or undermine resulting improvements in environmental quality.

2.2.3 *Explanation 3: Political Economy and Rent-Seeking Behavior*

In a first-best world where the social planner implements aggregate preferences, poor environmental quality implies low $MWTP_e$ or high marginal costs of environmental quality improvements. However, in a world of political economy constraints, poor environmental quality may stem from a social planner who does not maximize social welfare, as laid out in equation 7. Political economy factors add an additional element to the social welfare function, such as the social planner's own payoff or utility weights on her preferred group (see Fisman 2001 for a compelling example of utility weights). In many cases, this will result in a downward bias on the optimal level of environmental quality, by driving a wedge between aggregate preferences and the payoffs over which the social planner optimizes.

2.2.4 *Explanation 4: Measured $MWTP_e$ May Not Equal True $MWTP_e$*

Even a faithful social planner may choose suboptimally low levels of environmental quality if revealed preference measures of $MWTP_e$ do not reveal $MWTP_e$ as defined in equation (5). In particular, the market failures that are common in developing countries and behavioral heuristics and biases can cause measured $MWTP_e$ to diverge from $MWTP_e$. Throughout the remainder of the paper, we distinguish between measured $MWTP_e$ and the theoretical level of $MWTP_e$

that would be observed in the absence of any market failures or biases. We note from the outset that there may be opportunities to correct these market failures or behavioral biases in ways that produce Pareto improvements.

Market Failures from Development Economics

The market failures of developing economies may shape observed $MWTP_e$ and, as a result, the choice of environmental policy. If all markets function well, the transformation of y into environmental quality and self-protection and the transfer of y across periods is frictionless. However, information, credit, risk, or land/property rights imperfections may be reflected in measured $MWTP_e$, potentially resulting in a lower level of environmental quality than would be preferred in the absence of these market failures. The market failures common in developing countries can be modeled in a number of ways (for an overview see Bardhan and Udry 1999), and rather than adopt a single modeling approach, we offer an intuitive discussion of the relationship between market failures and $MWTP_e$. For these market failures, whether measured $MWTP_e$ is above or below perfect-markets $MWTP_e$ is theoretically ambiguous.

Revealed preference measures of $MWTP_e$ rely on individuals knowing the payoffs from investments in environmental quality. Residents of developing countries face a number of barriers associated with the quantity and quality of available information. Misinformation may be more persistent in developing countries because of a lack of liability rules around the provision of health information, or because markets fail to convey incentives for accurate information to producers. Developing country governments may also fail to provide accurate information about environmental quality and health. In addition, individuals may be illiterate or lack the education needed to understand the available information. Furthermore, in information-poor settings, individuals may neglect to include the effect of health on income (equation 3) when optimizing utility, resulting in revealed preference $MWTP_e$ measures below their full-information preferences.

Credit market failures, like many developing country market imperfections, stem from a difficulty in writing and enforcing contracts. High costs associated with monitoring borrowers and enforcing repayment where borrowers are liquidity constrained can lead to high interest rates or credit rationing (Conning and Udry 2007). Thus, in settings with credit market frictions, agents may not be able to pay upfront for investments that generate future improvements in environmental quality, and therefore in income or health. If environmental quality improvements involve upfront investments that pay off only in future periods, then income and other determinants of liquidity will confound measured $MWTP_e$.

Similarly, missing risk markets can lower individual willingness to invest in environmental quality improvements if the payoffs are uncertain and insurance is not available. Worsening environmental quality may increase the variability of income due to natural disasters or indirectly via health shocks. Missing insurance markets exacerbate individual agents' exposure to these risks and therefore can reduce measured $MWTP_e$, relative to settings where these markets exist. Furthermore, if an agent faces multiple environmental or health risks (such as both contaminated water and polluted air), the measured $MWTP_e$ to improve one dimension of environmental quality may be affected by the endowment of environmental quality on another dimension. Insuring one or both of the risks would therefore affect the valuation of the other. On the one hand, one environmental amenity might be a substitute for another such that the value of one amenity decreases with the endowment of the other one. On the other hand—and more likely—competing risks may lower measured $MWTP_e$. In an "O-ring" style model, measured $MWTP_e$ can be driven to zero in the presence of multiple uninsured risks (Kremer 1993). The effect of competing risks on measured $MWTP_e$ is not limited to environmental or health risks; any risk to survival will lower the value of a private investment in environmental quality that pays off in the future.

Consider also the example of imperfect land markets or poorly defined property rights. Weak land tenure may lower investments in environmental quality, such as tree planting or erosion mitigation, because agents are uncertain about their ability to retain the benefits from these investments. Incomplete property rights introduce frictions into the relationship between environmental quality and income, and to the transfer of income across periods. At the same time, where property rights are ill-defined, private bargaining solutions to environmental externalities are unlikely to arise, as Coase (1960) pointed out. In these examples, revealed preference measures of $MWTP_e$ will be biased downward because of weak property rights, relative to settings with strong property rights.

Behavioral Heuristics and Cognitive Biases

Numerous behavioral and cognitive biases are likely to affect revealed preference measures of $MWTP_e$ (see Shogren and Taylor 2008 for a review of behavioral environmental economics). Behavioral biases are most likely to affect decision making in situations where decisions are infrequent, outcomes are probabilistic, and consequences are in the future. In developing countries, market failures undermine the feedback that helps individuals learn from their previous decisions and exacerbate standard behavioral biases (Bertrand, Mullainathan, and Shafir 2004). For example, if the effects of health on productivity are distant or uncertain, they may be systematically underweighted for behavioral reasons. Additionally, unlike in developed countries where air, water, and food are all governed by a set of regulations that ensure high quality, residents of developing countries must continuously take actions to minimize exposure to ambient pollution (Mullainathan 2006; Duflo 2012). Research in other settings has demonstrated the power of defaults to shape behavior (e.g., Carroll et al. 2009) and the potential for repeated decision making to deplete cognitive energy (e.g., Vohs et al. 2008). Thus, psychological factors may introduce further distortions to revealed preference $MWTP_e$ measures.

2.3 *Public Goods and Externalities*

We now turn to the effect of public goods and externalities on the representative agent's choices and social planner's aggregation problem.

The simplified one period model has so far ignored spillovers across agents, such that the social planner's problem is identical to that of the representative agent. While a useful benchmark, it is also implausible, given that decisions that affect the environment involve externalities and public goods, almost by definition. Consider an economy with n identical agents, each of whom chooses consumption c_i, self protection s_i, and environmental quality improvement Δe_i. To allow for the possibility of externalities and to take into account the public goods features of environmental quality, let aggregate environmental quality be given by

$$(8) \qquad e = e_0 + \sum_{i=1}^{n} (\Delta e_i + a(c_i, s_i)).$$

Social marginal willingness to pay (SMWTP) for environmental quality accounts for externalities and public goods, so it reflects the first-best allocation and is defined by

$$(9)\quad SMWTP_e \equiv \frac{n}{\lambda_y^{SP}}\left(\frac{\partial u}{\partial e} + \frac{\partial u}{\partial h}\frac{\partial h}{\partial e}\right) + n\frac{\partial \Delta y}{\partial e} + n\frac{\partial \Delta y}{\partial h}\frac{\partial h}{\partial e}.$$

$SMWTP_e$ will exceed private $MWTP_e$ (as defined in equation 5) if environmental quality investments create public goods or positive externalities, or if consumption generates negative externalities.[10] Specifically, each agent's choice of Δe_i affects the utility of other agents (typically positively), and because of these externalities, agents do not make socially efficient investments in Δe_i. For example, a farming household does not enjoy the full environmental benefits associated with a switch to less harmful pesticides, and underinvests in the new technology even if it also improves the agent's own experienced environmental quality. Consumption externalities may also affect the environmental quality experienced by other agents (typically negatively). Social MWTP for self-protection ($SMWTP_s$) will also diverge from private $MWTP_s$ if self-protection generates negative externalities. For example, air conditioning protects an individual from poor environmental quality but creates negative externalities from energy consumption and greenhouse gas emissions. Thus, individuals may overinvest in self-protection relative to the first best allocation.

Generally, the public goods nature of environmental quality does not differ substantially between developed and developing countries, but externalities may be exacerbated by, and interact with, other market failures that are more prevalent in developing country settings, as described above. For example, in settings with multiple market failures, an otherwise efficient correction (e.g., a Pigouvian tax) to one market failure may be suboptimal in the presence of others (e.g., weak property rights).

3. *Existing Evidence*

A long history of theoretical and empirical economic research on environmental issues in developing countries has generated considerable insight into these issues.[11] The papers we describe in the remainder of the text stand on the shoulders of these pioneers (for example, Dasgupta and Mäler 1991, 1997). Our scope is limited to a relatively recent set of papers that prioritize causal inference and/or open new areas of inquiry, and still our coverage is incomplete. Our review of this literature leads us to conclude that a confluence of trends has created the conditions for a full-fledged field to bloom that is defined by the question of why environmental quality is so poor in developing countries. Its position at the intersection of environmental and development economics leads us to label this field envirodevonomics.

This section describes these trends and the opportunity they create. It then reviews the empirical evidence that attempts to quantify the impacts of poor environmental quality, as well as the existing evidence on the four potential explanations for the low levels of environmental quality in developing countries. Throughout, we highlight the areas where the opportunities for new research are greatest. We conclude this section with

[10] The social marginal utility of consumption is $\lambda_y^{SP} = \frac{\frac{\partial u}{\partial c} + n\left(\frac{\partial u}{\partial e} + \frac{\partial u}{\partial h}\frac{\partial h}{\partial e}\right)\frac{\partial a}{\partial c}}{1 - n\left(\frac{\partial \Delta y}{\partial e} + \frac{\partial \Delta y}{\partial h}\frac{\partial h}{\partial e}\right)\frac{\partial a}{\partial c}}$, which diverges from the private marginal utility of consumption because of negative consumption externalities.

[11] The journal *Environmental and Development Economics* is devoted to the topic and a recent special issue (vol 19 no 3) reflects on the publication's first twenty years.

a review of the theory and macroeconomics research that is relevant to envirodevonomics and continue to point out areas where further work would be especially fruitful.

3.1 *A Promising Confluence of Trends*

We believe that a confluence of at least four different trends has created the conditions necessary for a field to emerge that answers questions of great social and economic importance at the intersection of environment and development economics. First, and perhaps most obviously, there is a growing recognition of the extreme levels of pollution in many developing countries. As one example, measured Chinese and Indian air pollution concentrations exceed those ever recorded in any other country, which may be partially explained by the absence of reliable monitoring equipment in the first half of the twentieth century in the United States and Europe, but still highlights the extraordinary levels of pollution faced by the citizens of these countries today.[12] Relatedly, the literature on the health effects of pollution have advanced greatly in the last two decades although almost all of this research has been conducted in developed country settings, where pollution levels are less extreme (for example, Chay and Greenstone 2003; Currie and Neidell 2005; Currie and Walker 2011). At least in terms of human health, the stakes appear high.

Second, advances in modeling individual and firm behavior open the door to the estimation of parameters with a clear economic interpretation. Many of these advancements have occurred outside of the development or environmental literatures, but lend themselves well to theoretical application and empirical work on the determinants and effects of environmental quality in developing countries. In section 3.4, we summarize some of these theoretical advancements and highlight areas with substantial opportunities for innovation. The best empirical work will contribute to the identification of relevant parameters in the social planner's maximization problem, and therefore requires a clear theoretical underpinning of how revealed-preference measures are tied to a conceptual parameter.[13] As the studies below make clear, the greatest progress has been made in quantifying the impact of environmental quality on health $\left(\frac{\partial h}{\partial e}\right)$, rather than the marginal willingness to pay for such a change. In addition, the vast majority of studies related to $MWTP_e$ have focused on health channels, rather than direct effects $\left(\frac{\partial u}{\partial e}\right)$ or other indirect channels such as income $\left(\frac{\partial \Delta y}{\partial e}\right)$. Presumably, this is largely due to the challenges of measuring the relevant outcomes or of credibly identifying the effects of environmental quality on nonhealth parameters, though continued theoretical advancements will facilitate new and better empirical tests. Though our focus in this paper is on microeconomic topics and research, we also use section 3.4 to highlight the emerging macroeconomic work on growth and the environment.

Third, a number of breakthroughs in measurement and access provide researchers with new developing country datasets. Many countries, including China and India (see, for example, Greenstone and Hanna 2014), are beginning to open up to economic research on environmental quality. Technology, such as satellite imagery, allows researchers to bypass local data collection obstacles, which can be important where

[12] See relevant articles in a recent *Review of Environmental Economics and Policy* symposium on environmental issues in China (e.g., Vennemo et al. 2009; Cao, Garbaccio, and Ho 2009) and a recent paper on the geography of pollution in China (Zheng et al. 2014).

[13] Potentially, but by no means exclusively, the ones laid out in section 2.

government officials have incentives to distort environmental data (e.g., Chen et al. 2012 on gaming of air quality data in China). Indeed, a growing number of papers rely on satellite imagery to measure outcomes including pollution (Foster, Gutierrez, and Kumar 2009; Jayachandran 2009), deforestation (Burgess et al. 2012; Alix-Garcia et al. 2013), and economic activity (Henderson, Storeygard, and Weil 2011). Others use geographic information system maps to generate instruments for development outcomes (Duflo and Pande 2007; Dinkelman 2011; Lipscomb, Mobarak, and Barham 2013).

Fourth, there is a greater appreciation of the opportunities for conducting studies based on quasi-experimental and true experimental variation in key parameters. Just as in developed countries, many developing countries implement policies in seemingly arbitrary ways or use discrete rules to determine eligibility, which facilitates credible policy evaluation. Examples include China's Huai River policy, which provided free coal for winter heating to the north of the river but forbade winter heating with coal in the south (Chen et al. 2013), and Mexico's appliance buy-back program, which set subsidy levels based on past energy consumption thresholds (Davis, Fuchs, and Gertler forthcoming). In addition, there has been a near explosion of studies in developing countries that demonstrate the power of randomized control trials or field experiments to identify key parameters or relationships (e.g., Berry, Fischer, and Guiteras 2011; Duflo et al. 2013, 2014; Jack 2013; Kremer et al. 2011; Miller and Mobarak 2013; Bennear et al. 2013, and others still in progress). Experiments cannot, of course, answer many important questions in environmental and development economics, yet they serve as a complement to other empirical methods that may be better suited to understanding problems such as climate change (Dominici, Greenstone, and Sunstein 2014).

3.2 *Quantifying the Impact of Poor Environmental Quality*

Pollution levels in developing countries often exceed the standards set by regulators in developed countries and by global health recommendations (as shown in figure 1). Whether higher pollution levels translate into worse health outcomes depends both on the shape of the dose-response curve and also behavioral adaptations to the high levels of pollution, such as staying indoors on heavily polluted days and the purchase of air purifiers. An emerging body of evidence focuses on the relationship between pollution and health outcomes in developing countries, and suggests that poor environmental quality leads to sicker and shorter lives.[14]

Many of the relevant studies focus on the health impacts of air pollution $\left(\frac{\partial h}{\partial e}\right)$. For example, Almond et al. (2009) and Chen et al. (2013) use the geographic discontinuity created by a Chinese policy to subsidize coal north of the Huai River to estimate a significant increase in total suspended particulate matter (TSP). TSP has a large effect on mortality rates: increasing the long-term exposure to TSP by 100 $\mu g/m^3$ (or around half a standard deviation) is associated with a decrease of three years of life expectancy. This estimate is larger than the effect measured in developed countries and is more than five times the conventional OLS estimate. Because of China's extreme policies on migration during the period of study, the authors are able to study pollution effects on life expectancy, which is typically difficult to identify given migration and other self-selection responses to long run pollution exposure.

[14] See also the review article by Pattanayak et al. (2009), which focuses on four environmental health challenges in developing countries.

TABLE 1
Health Impacts of Pollution on Environmental Quality

Country	Pollutant	Health impact: magnitude	Methodology	Author (year)
Indonesia	PM	Infant mortality: 1.2 percent	Quasi-experiment	Jayachandran (2008)
Mexico	CO and PM	Infant mortality: elasticities of 0.227 (CO) and 0.415 (PM)	IV	Arceo et al. (2012)
China	TSP	Life expectancy: 2.5 years	Spatial discontinuity	Chen et al. (2013)
China	Water quality (index)	Stomach cancer deaths: 9.7 percent	Quasi-experiment	Ebenstein (2012)
Bangladesh	Fecal coliform	Infant mortality: 27 percent	Quasi-experiment	Field et al. (2011)
Kenya	E. Coli	Child diarrhea: 25 percent	RCT	Kremer et al. (2011)
Mexico	SO_2	Labor supply: 0.61 hours/week	Quasi-experiment	Hanna and Oliva (forthcoming)
India	Agrochemical	Multiple, child, and infant health	Quasi-experiment	Brainerd and Menon (2014)

Notes: Summary of empirical findings on the impact of pollution on environmental quality. Pollutants are abbreviated as follows: Particulate matter (PM), carbon monoxide (CO), total suspended particulate (TSP), sulfur dioxide (SO_2). RCT refers to a randomized controlled trial. Findings are as reported in the paper cited in the rightmost column. A lack of the relevant information for a number of the studies precludes the translation of the health impacts into elasticities.

Other papers in this literature focus on infant and child health outcomes to mitigate concerns about unmeasured lifetime exposure. Jayachandran (2009) takes an innovative approach to measuring the “missing children” associated with extreme pollution exposure during infancy and in utero due to forest fires in Indonesia. She uses satellite aerosol monitoring data to show that the particulate matter emitted by the fires led to a reduction in the size of the exposed birth cohort by 1.2 percent, an effect that is largely explained by prenatal exposure. A recent study by Arceo-Gomez, Hanna, and Oliva (2012) finds that exposure to carbon monoxide and particulate matter increases infant mortality in Mexico City. They use the frequency of thermal inversions, which trap pollutants close to the ground, as a source of plausibly exogenous variation in pollution exposure. Looking at exposure over the previous week, they find that a 1 $\mu g/m^3$ increase in particulate matter increases infant deaths per 100,000 by 0.24, while a 1 part per billion increase in carbon monoxide increases infant deaths per 100,000 by 0.0032 per week. Comparing their results to other studies, they find that—in elasticity terms—carbon monoxide has a larger effect on infant mortality in Mexico than in the United States, while the impact of particulate matter on infant mortality is similar to or smaller than in the United States.

A number of papers have also documented serious health impacts from poor water quality in developing countries. For example, Ebenstein (2012) studies the effects of industrial water pollution on stomach cancer in China. Like in Chen et al. (2013), historical restrictions on mobility in China make it possible to estimate long-run health outcomes with diminished concerns about selection. Specifically, Ebenstein (2012) finds that a decline in water quality by one grade (on a scale of 1 to 6) is associated with a 9.7 percent increase in deaths from digestive cancers.

Other studies look at the child health outcomes of poor water quality. Field, Glennerster, and Hussam (2011) find when households in Bangladesh switched from deep wells to surface wells contaminated with fecal bacteria, infant and child mortality from diarrhea disease increased by 27 percent. Brainerd and Menon (2014) use the seasonality associated with the application of fertilizers across different crops and regions of India to identify significant effects on numerous infant and child health outcomes including infant mortality, neonatal mortality, height-for-age z-scores, and weight-for-age z-scores. In their data, the effects are strongest in low socioeconomic status households. Kremer et al. (2011) find that a spring protection investment in Kenya reduced fecal contamination by 66 percent, which led to a reduction in child diarrhea of 25 percent. Duflo et al. (2014) find that providing communal water tanks and private bathing facilities and toilets to households decreases severe episodes of diarrhea by 30–50 percent over the long run.

As illustrated in the conceptual framework, better environmental quality may also have direct or indirect effects on income. While these relationships may be more difficult to quantify than the direct health impacts, they are important for the development of a comprehensive measure of the benefits of improved environmental quality. To the best of our knowledge, only two studies credibly show more direct effects of environmental quality on income (i.e., $\frac{\partial \Delta y}{\partial e} > 0$). First, Aragón and Rud (2013) show that the pollution associated with gold mining in Ghana has a negative impact on income from agriculture. They estimate an agricultural production function and analyze the effect of mining on the residuals of productivity, which is shown to correspond to an 18 percent increase in rural poverty. The empirical strategy relies on geo-referenced data on the location of mines and satellite imagery to measure air pollution (nitrogen dioxide). Second, some evidence suggests direct income effects from improved environmental quality associated with ecotourism. Sims (2010) uses placement rules for protected areas in Thailand, together with satellite data and survey measures of poverty, to document both a significant impact of protection status on deforestation and a positive impact on consumption and poverty reduction.[15] In this case, the channel appears to be increased local revenue from tourism.

Indirect effects have been documented via productivity and health $\left(\text{i.e., } \frac{\partial \Delta y}{\partial h} \frac{\partial h}{\partial e}\right)$. Using a difference in difference strategy, with additional variation in exposure from seasonal wind patterns, Hanna and Oliva (forthcoming) examine the effect of a decrease in pollution resulting from the closure of a refinery in Mexico City. They find that a one percent decrease in sulfur dioxide concentrations increased labor supply by 0.61 hours per week. They present suggestive evidence that the effects are driven by child health, which affects parental labor supply. Pitt, Rosenzweig, and Hassan (2012) find evidence that arsenic exposure lowers cognition and results in lower schooling attainment using biological measures of arsenic (i.e., toenail clippings) and variation associated with genetic predisposition to store arsenic in the body. Kremer et al. (2011) also measure the effect of pollution on productivity in their study of springs in Kenya and find that improvements to water quality

[15] Using matching methods, Andam et al. (2010) provide additional evidence from both Costa Rica and Thailand on the poverty alleviation of protected areas. For a broader review of empirical work on forests and forest conservation in developing countries, see Ferraro et al. (2012).

did not increase school attendance among primary-school children.

Taken as a whole, these papers indicate that the health burden of air and water pollution in developing countries are substantial and that the productivity and income effects may also be important. There is still a great deal to learn about dose-response functions, the distribution of impacts, and the nonhealth outcomes. All of these are promising areas for future research, with the greatest contribution likely to come from studies that go beyond quantifying the health impacts to investigate both economic consequences and underlying mechanisms.

3.2.1 *Willingness to Pay for Environmental Quality*

A high health burden from environmental quality in developing countries does not directly imply a high $MWTP_e$. Instead, the studies reviewed in the previous subsection aim to describe $\frac{\partial h}{\partial e}$ or $\frac{\partial \Delta y}{\partial h}\frac{\partial h}{\partial e}$. However, the $MWTP_e$ associated with these changes is the relevant parameter for the social planner (see equation 9) and central ingredient in the determination of optimal policy.

Few studies attempt to develop revealed preference estimates of $MWTP_e$.[16] Kremer et al. (2011) uses a randomized controlled trial to generate exogenous variation in water quality across springs in Western Kenya. They find that households are only willing to pay about $11 per year for clean water, where $MWTP_e$ is calculated from rural wage rates and revealed willingness to walk to clean water. This translates into a revealed preference value of a statistical life of USD2013 860, which is four orders of magnitude lower than accepted VSL numbers in the United States.[17] In addition, the same households' revealed $MWTP_e$ is substantially lower than the valuations they give in a contingent valuation survey. Other studies that measure the *MWTP* for health in developing countries may offer estimates of the appropriate valuation to assign to $\frac{\partial u}{\partial h}$. The empirical literature valuing improvements to health in developing countries is reviewed by Dupas (2011) and is consistent with measured *MWTP* well below that in developed countries.

Overall, what little evidence we have clearly suggests that observed levels of $MWTP_e$ are low. It is an open question as to whether the low measured $MWTP_e$ in these studies reveals a $MWTP_e$ that would be low even if well-functioning markets or if market failures reduce measured $MWTP_e$ relative to its "true" value, as discussed in section 2.2.4. For example, the paucity of hedonic studies in developing countries could reflect imperfections in the land and labor markets that make them ill-suited for inference about $MWTP_e$ (although it surely also reflects the limited availability of high quality land price and labor market data). Even the Kremer et al. (2011) study relies on market wages to convert walking time to monetary units, in a setting where labor markets are highly imperfect. Our judgment is that there is hardly a more important topic for future study than developing revealed preference measures of $MWTP_e$ that capture the aesthetic, health, and/or income gains from environmental quality.

[16] The well-identified empirical literature on willingness to pay for environmental quality in developed countries is also extremely sparse.

[17] Other estimates of VSL numbers for developing countries are highly variable depending on the methodology employed (see Viscusi and Aldy 2003 for a summary and León and Miguel 2012 and Bhattacharya, Alberini, and Cropper 2007 for examples of different methods). Many revealed preference studies of VSL rely on hedonic regressions to isolate the risk–price trade-off, which relies on assumptions of well functioning markets that may not hold in developing country settings.

3.2.2 *Willingness to Pay for Self-Protection*

A larger number of studies measure $MWTP_s$, which identifies $MWTP_s$ as defined in equation (6) under the assumption that market failures do not bias valuations. Berry, Fischer, and Guiteras (2011) observe a median willingness to pay for a water filter in Ghana that ranges from \$1.80 to \$2.40, depending on how the valuation was elicited. Overall, the filter appears to reduce self-reported diarrheal incidents after one month of use by 8 to 14 percent. They find only weak evidence of a relationship between measured demand and self-reported diarrheal reductions from the filter. Strategies for self-protection are likely to be diverse and more evidence on the potentially costly choices that households make in the face of pollution, such as adjustments to migration or fertility decisions, will help quantify households' $MWTP_s$ to avoid pollution.

$MWTP_s$ may also vary within the household if the health burden of poor environmental quality is unevenly distributed across household members. Miller and Mobarak (2013) show that women in Bangladesh have a stronger preference for low-emissions cookstoves than do men. In the study setting, men often manage money and women are liquidity constrained, such that many women who express a preference for the low-emissions stove are unable to purchase it, while men are more likely to implement their stated preferences. Pitt, Rosenzweig, and Hassan (2010) also find meaningful gender differences in the health impacts of indoor air pollution and show that status within the household is an important determinant of exposure. Thus, household-level measures of $MWTP_s$ may not accurately capture within-household heterogeneities. Both Berry, Fischer, and Guiteras (2011) and Miller and Mobarak (2013) measure marginal willingness to pay for a (unfamiliar) product that affects experienced environmental quality, yet neither measures $MWTP_e$ for the ultimate change in environmental quality or *MWTP* for health outcomes or beliefs about how the technology will affect health.

3.3 *Existing Evidence on the Explanations for Poor Environmental Quality*

The limited evidence on $MWTP_e$ in developing countries suggests extremely low valuations. While more evidence is needed, this finding raises questions about the underlying causes. In addition, while low $MWTP_e$ is a sufficient condition for poor environmental quality in developing countries, it is not the only possible explanation. Next, we turn to the evidence on each of four possible explanations for poor environmental quality in developing countries, including why $MWTP_e$ might be low.

3.3.1 *Explanation 1: High Marginal Utility of Consumption*

Recall from equations 5 and 9 that $MWTP_e$ is determined not only by the endowment of environmental quality, but also by the marginal utility of income. Increasing income or wealth may increase $MWTP_e$ as the marginal utility of consumption decreases. An ideal experiment would measure how $MWTP_e$ changes with an exogenous change in income. However, most experiments generate only short-run shifts in income, and it may be challenging to find a quasi-experimental design that credibly identifies the effects of permanent income shocks. Evidence on the individual-level income–$MWTP_e$ relationship is extremely scarce in both developing and developed countries.

Hanna and Oliva (2014) offer some direct evidence by examining the fuel choices of households in India following the randomized roll out of a transfer program that had measurable effects on income and assets. While energy use by treated households increases substantially, it does not become much cleaner; the shift from dirtier kerosene to cleaner electricity is offset by an overall increase in kerosene purchases, and the cooking technologies that are responsible for most indoor air pollution do not improve. Other studies that are relevant to the relationship between income and $MWTP_e$ or $MWTP_s$ provide mixed correlational evidence. Jalan and Somanathan (2008) document higher expenditures on water quality among households in urban India with more assets. Consistent with this result, Kremer et al. (2011) find that households with more education or assets are more willing to walk to access improved water sources. On the other hand, neither Berry, Fischer, and Guiteras (2011) nor Ashraf, Berry, and Shapiro (2010) find a correlation between revealed willingness to pay for water purification technologies and assets. The relationship between income and $MWTP_s$ or $MWTP_e$ in all of these studies is correlational, and further research on the topic will help determine whether the high marginal utility of consumption that accompanies very low incomes drives low private and social $MWTP_e$.[18]

As suggested by the conceptual framework, higher incomes might be associated with both higher $MWTP_e$ and also larger impacts on the environment $\left(\text{if } \frac{\partial a}{\partial c} > 0\right)$. Several recent papers provide evidence that as incomes in developing countries increase, there is a negative causal impact on environmental quality. Plausibly exogenous variation in income to estimate these impacts is generated through a randomized cash transfer program in Mexico in the studies by Alix-Garcia et al. (2013) and Gertler et al. (2013). Alix-Garcia et al. (2013) find that the additional income associated with the *Oportunidades* program increased deforestation due to higher consumption of land-intensive goods, such as beef. Their study implements a community level regression discontinuity design based on the rules that determine program eligibility to study deforestation as measured by satellite images. They combine this community-level analysis with household survey measures of consumption from the randomized pilot phase of the program.

Gertler et al. (2013) use a different source of identification under the same program to find a similar impact on environmentally harmful consumption. In their case, the outcome of interest is the purchase of energy-intensive durable goods, specifically refrigerators, and they use a combination of the random variation of when communities were phased in to the program and household-level variation in the income flow due to household structure.[19] They find that the income shock of the transfer increased refrigerator purchases, and therefore household energy consumption, with the largest effects for households that received the income over a short period of time. They use these empirical results to simulate different development pathways, and provide the insight that economic growth that benefits the poor increases energy consumption and the related negative externalities more than less progressive patterns of growth. These findings do not, of course, directly imply that households have low $MWTP_e$ or that aggregate $MWTP_e$ does not increase with income. They do, however, highlight the importance

[18] A stated preferences study by Israel and Levinson (2004) uses a World Values Survey question to correlate individual-level income and stated $MWTP_e$ across and within countries. They use the survey data to test different mechanisms underlying the Environmental Kuznets Curve hypothesis (the inverted-U shaped relationship between GDP and environmental quality) and find a strong correlation between income and marginal stated $MWTP_s$ but no systematic relationship between per capita GDP and stated $MWTP_s$. Country fixed effects explain a large share of the variation.

[19] The transfer amount differed by gender and grade of school-aged children.

of externalities from consumption and self-protection ($a(c, s)$) that may increase more quickly with income than does private investment in environmental quality (Δe_i).

3.3.2 *Explanation 2: High Marginal Costs*

Costs of improving environmental quality are affected by the capacity to design, implement, or enforce environmental policy and by the relationship between environmental quality improvements and other investments in the economy.[20] Empirical evidence on the magnitude of the marginal cost of environmental quality improvements $\frac{\partial c_e}{\partial \Delta e}$ is important for solving the social planner's maximization problem, and high marginal cost is a sufficient explanation for why environmental quality is so poor in developing countries. Many countries have tough environmental regulations on the books, yet have trouble achieving their environmental goals (Greenstone and Hanna 2014), potentially because of the high costs of doing so.

High costs of improving environmental quality that are driven by poor policy design and implementation do not imply that marginal abatement costs in developing countries are high. In fact, where existing policies are lax, marginal abatement costs may be relatively low. However, evidence on the marginal cost of pollution abatement in developing countries is scarce. Recent research in the United States has begun to compare marginal abatement costs across sources to identify the true costs of pollution abatement (Fowlie, Knittel, and Wolfram 2012). Similar research in developing country settings would provide a more complete picture of the costs of improving environmental quality in developing countries and across countries, which is particularly relevant for global pollutants such as greenhouse gases (see section 4). In developing countries, poor policy design may target actions at the high end of the marginal abatement cost curve, and poor implementation capacity may result in missed economies of scale associated with the centralized provision of environmental quality. The result is high marginal costs of environmental quality improvements.

Many environmental quality improvements are most cheaply achieved through aggregate investments, and taxation offers the practical means for aggregating individual contributions to environmental quality (Δe_i). However, a growing number of studies highlight the challenges in collecting taxes in developing countries (see Besley and Persson 2013 for a review), and empirically investigate the underlying causes of poor tax compliance (e.g., Kumler, Verhoogen, and Frías 2013; Pomeranz 2013). As the taxation literature makes clear, the social cost of investing in public goods, including environmental quality, is higher when raising revenue is difficult. Weak capacity for taxation will also interfere with efforts to implement market-based pollution regulations, such as Pigouvian taxes.

A lack of scientific expertise, poor policy guidance, or low levels of accountability may result in poorly chosen policy objectives or misdirected regulations. A striking case of this is demonstrated in Field, Glennerster, and Hussam (2011), which shows that a successful arsenic information campaign led to worsened health by encouraging households to switch from arsenic-contaminated deep wells to surface water contaminated with biological pathogens that cause diarrhea in children. Taking advantage of the quasi-experimental distribution of below-ground arsenic, the authors document that, on net, the arsenic campaign led to a 27 percent increase in infant and child mor-

[20] Where state intervention fails, collective action or private provision of public goods may still improve environmental quality. There is a large literature in both economics and political science on this topic, much of it using case studies (see Ostrom 2000 for a review).

TABLE 2
Evidence for High Marginal Costs

Country	Finding	Methodology	Author (year)
Brazil	Decentralization increases water pollution	Fixed effects	Lipscomb and Mobarak (2011)
Mexico	Policy loopholes undermine effectiveness	Temporal discontinuity	Davis (2008)
Mexico	Voluntary certification lowers regulatory costs	Structural identification	Foster and Guiterrez (2012)
Mexico	Large inframarginal payments lower policy impacts	Fixed effects, RD	Davis et al. (forthcoming),
			Boomhower and Davis (2014)
Bangladesh	Policy has large unintended consequences	Quasi-experiment	Field et al. (2011)
Philippines	Public and private provision are substitutes	Fixed effects, IV	Bennett (2012)
India	Public support improves the effectiveness of environmental policies	Fixed effects	Greenstone and Hanna (2014)

Notes: Summary of empirical findings on the marginal costs of environmental policies in developing countries. Further details on the studies are described in the text.

tality. The paper also highlights the challenge of multiple environmental risks, and an inability of households or policymakers to accurately rank them. Szabo (2014) provides another clear example of suboptimal policy making. Using a very different methodological approach, she examines the welfare implications of South Africa's Free Basic Water policy. Rich household panel data, together with variation in nonlinear tariffs across households and over time, identifies a structural demand model. Her results imply that, without a loss of revenue, the social planner could reallocate the existing subsidy to increase welfare.

Unanticipated effects of environmental regulations also arise through agents' responses to the policies. For example, Davis (2008) finds that a policy to restrict driving in Mexico City according to license plate number had no effect on pollution levels. Instead, the number of registered cars increased, presumably because consumers could bypass the regulation by purchasing an additional car with different plates.[21] In Mexico City, implementation of the policy and the costs to households are estimated at over 300 million dollars annually and generated no improvements in environmental quality. Policy implementers also have incentives to exploit loopholes in policy design. Duflo et al. (2013) study the performance of third-party auditors used by the environmental regulator in Gujarat, India to identify industrial plants that exceed the emissions standards. When plants choose and pay the auditors, as is the norm, they find that the system is corrupted. Auditors systematically

[21] Similar driving restrictions have been introduced and evaluated in other cities including Beijing, Santiago, and São Paulo, with mixed success (Gallego, Montero, and Salas 2013; Lin, Zhang, and Umanskaya 2011; Viard and Fu 2011).

reported plant emissions just below the standard, although actual emissions were typically higher. The social costs of these policy-making oversights are large.

Poor targeting also increases the marginal cost of environmental quality improvements. Another program in Mexico that subsidized the purchase of energy-efficient appliances performed very poorly, actually increasing energy consumption for some appliances, while ex ante engineering estimates indicated that the program would pay for itself in energy savings (Davis, Fuchs, and Gertler forthcoming). The extreme overestimate of the program's effectiveness was due to a combination of changes in the types of appliances purchased, usage patterns, and the inclusion of many inframarginal households (Boomhower and Davis 2014; Davis, Fuchs, and Gertler forthcoming).

In settings with low enforcement capacity and heterogeneous benefits from environmental quality, decentralization may pose a useful solution for improving monitoring and accountability (Bardhan 2002; Lemos and Agrawal 2006). Decentralization of policies for environmental quality may therefore improve local welfare, while generating an incentive to divert pollution to neighboring jurisdictions. Sigman (2002) analyzes this problem with respect to international water pollution and shows that pollution levels are elevated in rivers upstream of an international boundary. Lipscomb and Mobarak (2011) analyze a similar problem across counties in Brazil. They use changes in district boundaries to generate evidence from Brazil that, within a jurisdiction, pollution levels are highest where the river is close to entering a downstream jurisdiction. Without centralized enforcement capacity, these types of environmental externalities may go unpenalized. While decentralization may lower the costs of improving environmental quality locally, it may simply shift these costs to other jurisdictions if pollutants are mobile. On the other hand, Kahn, Li, and Zhao (forthcoming) provide clear evidence that interjurisdictional spillovers also depend on incentives set further up the bureaucratic chain. They exploit a change in the rules for promotion of local officials in China that reward pollution reductions along administrative boundaries. The incentives set by the centralized government make progress toward internalizing the interjurisdictional externalities. For pollutants that cross international boundaries, the problem is more complex, and we return to it in the discussion of climate change in section 4.

Other investments in the economy, by policymakers, firms, and individuals, affect the marginal cost of improving environmental quality, and privately optimal investment choices change in response to new environmental regulations or improvements in environmental quality. For example, the marginal costs of improving environmental quality may appear higher to the social planner if individual responses to public investments are taken into consideration. While public (or privatized) provision itself may improve efficiency, it will not improve experienced environmental quality if compensatory changes in behavior reduce private investments in self-protection. Bennett (2012) studies such a case in the Philippines and argues that improved water supply infrastructure resulted in lower private sanitation investments. Consistent with this finding, Berry, Fischer, and Guiteras (2011) show a negative correlation between access to an improved water source year-round and measured willingness to pay for an in-home water filter. This suggestive evidence on the substitutability of public and private investments does not imply that public investments are inefficient, just that the marginal costs may be underestimated if the relationship between public and private investments is ignored. Further research on the interaction between public and private resource management and environmental quality provision is needed.

Complementarities between environmental policy and infrastructure may also affect the marginal costs of environmental quality improvements. For example, centralized infrastructure has the potential to resolve common pool resource challenges in settings where the fixed cost of private resource extraction is high by creating a feasible setting for marginal cost pricing (Sekhri 2011). Poor infrastructure can further hurt consumers by limiting competition among service providers (Ryan 2014). Low levels of competition potentially undermine incentives for reducing the marginal cost of environmental quality improvements. Consistent with this, Galiani, Gertler, and Schargrodsky (2005) show that better firm incentives associated with privatization improved water quality and health outcomes in Buenos Aires. Their study offers compelling evidence on the positive health effects of improved infrastructure to deliver environmental quality. More generally, how firms respond to environmental regulations depends not only on the costs imposed by the regulation, but also on how it affects their competitors. Lipscomb (2008) examines the response of firms in India to an increase in enforcement and finds that firms adjust away from the production of dirty output, though profits increase in polluting sectors where competition was reduced as a result of the change in regulation.

Additional evidence is starting to accrue about the types of policies that generate better environmental outcomes at reasonable cost. For example, policies that receive broad popular support may manage to avoid some of the evasion that undermines Mexico Citys pollution control efforts (documented by Davis 2008 and Oliva forthcoming). Of course, the regulations with broad popular support may also be the ones that impose little burden or generate large benefits for affected households. Greenstone and Hanna (2014) compile a comprehensive dataset of pollution levels and policy changes in India and find that the most successful policies are the ones with a broad internal base of support, rather than those led by bureaucrats and institutions. This translates to significant policy impacts on ambient air pollution, but not on water quality, where the policy process was less transparent. The Duflo et al. (2013) study of third-party auditors described above finds that auditors report on pollution emissions more truthfully when the audit market is restructured to mitigate incentives for conflicts of interest. Further, plants reduce their pollution emissions, presumably because they are concerned about sanctions from the regulator who is receiving substantially more reliable information on which plants violate the standards.

Policies designed explicitly to overcome information asymmetries and improve targeting, such as the auction-based allocation of land use subsidies studied in a field experiment by Jack (2013), may help lower the cost of policies that improve environmental quality in developing countries.[22] In a different setting, Foster and Gutierrez (2009, 2012) investigate whether voluntary environmental programs can be effective, potentially addressing poor government enforcement through policy design. They rely on satellite measures of pollution concentrations and use an instrumental variables strategy to show that participation in a voluntary pollution reduction program in Mexico led to a 16 percent decrease in pollution-driven infant mortality. This reduction is largely because participating firms agreed

[22] Other studies highlight the importance of targeting for decreasing the information rents in payments for environmental services. Arriagada et al. (2012) use difference and difference with prematching on observables to evaluate the impacts of land-use subsidies in one region of Costa Rica. They find larger impacts than do previous analyses of the Costa Rica program (e.g. Robalino and Pfaff 2013) and suggest that the difference is due to superior targeting in their region of study. See also a recent paper by Alix-Garcia, Sims, and Yañez-Pagans (2012).

to a voluntary audit in exchange for a two year inspection exemption. This allowed the regulator to better target inspections, leading to pollution reductions by uncertified firms. These findings suggest that policies that offer some information revelation component can improve how regulations are targeted, which may be particularly important for cost effective environmental quality improvements where monitoring and enforcement capacity is weak.

3.3.3 *Explanation 3: Political Economy and Rent-Seeking Behavior*

The conceptual framework distinguishes between high marginal costs associated with weak capacity or missing infrastructure and political economy factors that distort the social planner's maximization problem. Empirical studies on the effects of political economy considerations and rent-seeking behavior on environmental quality provide estimates of these distortions, which may take the form of an additional parameter in the welfare equation. For example, the policymaker's and/or bureaucrat's own utility may enter the function that determines policy, or there may be unequal welfare weights assigned to specific groups. The supply or withholding of environmental quality by the social planner may be one form of affecting distributional outcomes across groups, as shown by Feler and Henderson (2011) for water connections in Brazil. On the other hand, utility weights in the social planner's function may also help correct for an unequal burden of poor environmental quality in developing countries.

There is an emerging empirical literature that finds evidence for rent seeking as an explanation for poor environmental quality. Oliva (forthcoming) studies a pollution control policy in Mexico City and finds extensive corruption in the smog emissions testing program for private vehicles. She uses data from smog testing centers to implement both structural and reduced form analyses. The results suggest that at least 9.6 percent of old-car owners paid bribes of $20 to circumvent the regulations.

Among elected officials, rent-seeking opportunities can also undermine policy implementation. Compelling evidence to this effect is presented by Burgess et al. (2012), who find that corruption increases deforestation in Indonesia. A combination of satellite imagery, data on electoral cycles, oil prices, and district boundaries are used to show that in years when oil revenues are low, illegal logging increases. Enforcement of environmental policies (in this case, forest laws) may therefore suffer when natural resources are viewed as a source of rents. More broadly, if taxation provides an opportunity for rent seeking (and it does, according to Olken and Pande's 2012 review of the literature on corruption), then the aggregation of individual preferences will be distorted. On the other hand, new evidence indicates that improving incentives for bureaucrats can both reduce corruption and improve monitoring and enforcement outcomes in developing countries (for example, Duflo et al. 2013). It is apparent that, at least in some settings, part of the cost of environmental quality improvement is therefore increased by rent seeking and other corrupt behavior.

Firms may respond to regulatory settings distorted by opportunities for rent capture by modifying their objective function in ways that undermine competitiveness and reduce environmental quality. For example, McRae (2015) describes the impact of government subsidies for public services, sewerage, and electricity, which undermines firm incentives to improve infrastructure quality in Colombia. Because firms receive transfers from the government in lieu of payments from customers, they have little incentive to improve infrastructure (and therefore cost recovery) themselves. The "grabbing hand" model of government suggests that

TABLE 3
EVIDENCE FOR POLITICAL ECONOMY DISTORTIONS TO ENVIRONMENTAL POLICY

Country	Sector	Finding	Methodology	Author (year)
India	Regulatory	Corruption undermines pollution monitoring	RCT	Duflo et al. (2013)
Indonesia	Forestry	Illegal deforestation provides income for bureaucrats	Fixed effects	Burgess et al. (2012)
Mexico	Transportation	A market for bribes bypasses smog checks	Structural identification	Oliva (forthcoming)

Notes: Summary of empirical findings on political economy and rent seeking. Greater detail on the studies is provided in the text.

corruption and state owned enterprises discourage entrepreneurship and distort firm entry and exit decisions (Shleifer and Vishny 2002). Some of the low observed total factor productivity among firms in countries such as India and China may be a direct result of government intervention or other market failures that distort resources away from the most productive firms (Hsieh and Klenow 2009). When rent-seeking politicians set regulation, they may therefore undermine competition that would help increase the efficiency and lower the pollution intensity of the average firm.[23]

While utility weights in the social planner's maximization problem are most often associated with handouts and political favors (e.g., Fisman 2001), they may also serve the function of correcting socially undesirable distributions of the burden of poor environmental quality. Within the household, women and children are more likely to bear the cost of indoor air pollution and poor water quality (as discussed in section 3.2.2). And within many developing country settings, poor and marginalized groups are often described as dependent on natural resources, either as a primary source of income or for consumption smoothing (Hassan, Scholes, and Ash 2005). Thus, the burden of poor environmental quality may fall disproportionately on these already vulnerable groups. Whether such outcomes are avoided may depend on explicit weights in the social welfare function, which carry their own political economy considerations.[24] Further research on the causal relationship between environmental quality, social status, and economic vulnerability will help inform open questions about the incidence of the pollution burden in developing countries.

3.3.4 *Explanation 4: Market Failures and Behavioral Biases*

Information, credit, risk, or land/property rights market failures may distort measured $MWTP_e$ away from its value in a world

[23] Ryan (2014) shows related evidence that reduced competition harms electricity provision in India. Dasgupta, Lucas, and Wheeler (1998) show evidence from Brazil and Mexico that small firms are both more prevalent and have much higher pollution levels in poorer regions, though these results can be partially explained by the sectors in which small firms operate.

[24] See, for example, the extensive discussion of indigenous rights to resource use in the UN's State of the World's Indigenous People (UN 2009).

TABLE 4
Evidence on Market Failure-Based Distortions to MWTP

Market failure	Country	Finding	Methodology	Author (year)
Property rights	Rwanda	Formal titling increased soil conservation	Spatial discontinuity	Ali et al. (2014)
Information	India	Information increased investments in water filters	RCT	Jalan and Somanathan (2008)
Information	Bangladesh	Information increased switching to clean water sources	Quasi-experiment	Madajewicz et al. (2007)
Information	Bangladesh	Information content determined effects on behavior	RCT	Bennear et al. (2013)
Credit	Bangladesh	Access to credit increases WTP for self protection	RCT	Guiteras et al. (2014)
Labor		No empirical evidence		
Risk		No empirical evidence		

Notes: Summary of empirical findings on the effects of market failures on MWTP for environmental quality, classified according to the market failures described in the text.

free from market failures (as in equation 5). Empirical evidence on the topic is scarce, though the potential to evaluate the environmental effects of interventions that improve markets in developing countries is high.

Some evidence suggests that information provision can have substantial effects on measured $MWTP_e$ and on investments in self-protection, which implies that information market failures may distort revealed preference measures. In a randomized experiment, Jalan and Somanathan (2008) provide Delhi residents with information about the quality of their tap water and find a significant change in expenditures following the treatment. Individuals who learn that their water is dirty are 11 percentage points more likely to purchase in-home treatment and overall expenditures on in-home treatment increase by 6.5 percent. Madajewicz et al. (2007) also find a significant response to information about water quality in Bangladesh, while Pattanayak et al. (2009) show that intensive information designed to generate social pressure as well as awareness increased latrine adoption in Orissa, India. Ashraf, Jack, and Kamenica (2013) focus instead on information about the self-protection technology. They offer an unfamiliar water purification solution at randomly varied prices to urban consumers in Zambia and observe that households are more price sensitive when they have more information about the product. In the absence of other sources of information, households may infer product quality from price. Another study in Bangladesh suggests that the effect of information is sensitive to how it is delivered (Bennear et al. 2013). The authors show that providing households with complicated information about well contamination leads to suboptimal decisions in water choice.

These studies relate to a large literature in development economics that describes the information and learning challenges associated with technology adoption (for a review of the technology adoption literature, see Foster and Rosenzweig 2010). A household that has never experienced clean water may not know the benefits of experimenting with technologies or behaviors that improve water quality. To the extent that peers and neighbors offer transferrable information through their own actions, social learning is more likely to occur (Foster and Rosenzweig 1995; Conley and Udry 2010). A trusted government agency may be able to help overcome information failures in developing countries. However, individuals may not trust official information sources—in some cases, for good reason, as shown in the study by Field, Glennerster, and Hussam (2011) described above. One reason for low measured $MWTP_e$ in developing countries may therefore be a lack of clear and trustworthy information about the benefits of improved environmental quality.

Evidence on the effects of market failures other than information are less common. In one existing study in Rwanda, Ali, Deininger, and Goldstein (2011) use a spatial regression discontinuity design to measure the impacts of a land titling program on a number of outcomes, including investments in soil fertility. They show that more secure land titles increased investments in environmental quality, particularly among female-headed households, for whom the change in tenure security was likely to be most dramatic.

Missing capital markets may also reduce incentives for investments with long-run payoffs, which includes many environmental quality investments. Guiteras et al. (2014) randomly introduce different types of credit for water purification filters in Bangladesh and document a positive relationship between measured willingness to pay for a filter and credit availability. Their study offers clear evidence on the distortion to revealed preference measures of $MWTP_e$ that emerge from settings with missing credit markets for investments with long-run payoffs or largely nonmonetary benefits. At the same time, credit constraints may inhibit investment in environmentally damaging production and consumption. For example, Assunção et al. (2013) show that a restriction on credit in Brazil lowered deforestation rates, likely by decreasing land-intensive livestock investments. These results are consistent with Alix-Garcia et al.'s (2013) finding that income transfers under *Oportunidades* led to greater deforestation in Mexico.

Because land, risk, and capital market failures are prevalent in developing countries, more evidence is needed about how these constraints affect the measurement of $MWTP_e$. In particular, the size and direction of the gap between measured $MWTP_e$ and $MWTP_e$ in the absence of these constraints, and the costs of narrowing the gap, are necessary policy inputs. The substantial literature in development economics documenting plausibly exogenous sources of variation in market function should help facilitate future research.

The behavioral implications of defaults and cognitive depletion associated with the constant active decisions that residents of developing countries must make to raise their experienced environmental quality may partly explain low revealed $MWTP_e$. Though studies of the behavioral effects of defaults have proliferated in other contexts, they have received relatively little attention for environmental decision making.[25] Devoto et al. (2012) use a randomized experiment to study the take-up and impacts of a subsidized program to connect households to the municipal water system in Morocco. They find that small administrative barriers have a large impact on take-up, and that households who received tap water experience a substantial improvement in quality of life and mental health, in spite of the lack of health impacts. Also related to

[25] A developed-country exception is Lofgren et al. (2012), who study the effect of defaults on the purchase of carbon offsets.

demand for clean water, Ashraf, Berry, and Shapiro (2010) provide evidence against the sunk cost fallacy associated with paying for self-protection. This study falls into the growing literature on measuring *MWTP* for health investments in developing countries (Dupas 2011), some of which highlights behavioral biases. Behavioral biases and psychological factors offer a promising direction for future research, which can help identify the gap between measured $MWTP_e$ and $MWTP_e$ in the absence of market failures.

3.4 *Theory and Macroeconomics*

The majority of the papers reviewed thus far are solidly within the realm of empirical applied microeconomics. However, as we suggest in section 3.1, new developments in theory and modeling facilitate empirical tests at the intersection of environmental and development economics. At the same time, the challenges laid out in this paper present opportunities for new applied theory, which will help advance understanding of the challenges at the core of this nascent subfield.

An exhaustive review of theoretical progress relevant to environmental quality in developing countries is well beyond the scope of this paper. Instead, we highlight three areas where new applied theory is emerging or may be particularly important for advancing our understanding of environment and development issues. First, as section 2.2.4 makes clear, the market failures of environmental economics may interact with the market failures of development economics. While substantial theoretical literatures describe each in isolation (see Stiglitz 1989; de Janvry, Fafchamps, and Sadoulet 1991 for seminal works in development economics and Baumol and Oates 1988; Cornes and Sandler 1996 for environmental economics), the implications of these interactions require additional modeling to derive specific predictions. Second, environmental economics has benefitted enormously from the application of theory and methods from industrial economics to questions of optimal environmental regulation and pollution control (e.g., Fowlie 2009, 2010; Ryan 2012). Extending this work to developing countries, where contracts are difficult to enforce, information asymmetries are potentially large, and corruption affects the entry and exit of firms, offers rich grounds for new innovation in applied theory. Finally, behavioral economics continues to generate new theories relevant to individual decision making in developing countries (e.g., Bertrand, Mullainathan, and Shafir 2004; Banerjee and Mullainathan 2010; Bryan, Karlan, and Nelson 2010). Environmental applications contain many of the ingredients for interesting behavioral theory—low probability outcomes, social spillovers, and future impacts—and more complete descriptions of individual and household decision making will help the field of environmental and development economics progress.

Additionally, there is a small but growing and insightful macroeconomics literature at the intersection of environment and development. Recent papers by Fischer and Heutel (2013) and Smith (2012) provide an overview of recent work and potential research directions at the intersection of traditional macroeconomics and environmental economics. Fischer and Huetel describe a nascent literature on economic growth that considers induced innovation and path dependency for environmental technologies. For example, recent theoretical work by Acemoglu et al. (2012) and Hemous (2013) considers the effects of carbon taxes and research subsidies on innovation in a single-economy or two-economy model, respectively. The models presented in both papers find support for the use of research subsidies in clean sectors, particularly when subsidies in a rich country generate technological spillovers for a poor country. A number of related papers have followed this work, and are described by Fischer and Heutel (2013) in their review. The directed technological change literature is not the only macroeconomic subfield that has embraced environment–development or environment–growth topics. Studies that use integrated assessment models of climate change necessarily consider growth–environment feedbacks (see Kelly and Kolstad 1999; Nordhaus 2013; Hassler and Krusell 2012) and the literature on trade and the environment (for example, Copeland and Taylor 2005; Shapiro 2013) has a history of work on pollution havens and environmental trade barriers that affect developing countries.

4. *Climate Change*

We believe that climate change is the most important topic in envirodevonomics. It is often referred to as an existential threat and this is literally true for some developing countries (e.g., parts of Bangladesh are at risk of disappearing due to sea-level rise). More broadly, the greatest damages are projected to occur in today's developing countries, especially those in the tropics. At the same time, today's developing countries are expected to be the largest emitters of greenhouse gases in the coming decades due to their projected growth in GDP and energy consumption (see Gertler et al. 2013; Wolfram, Shelef, and Gertler 2012); China is currently the largest emitter of CO_2 in the world and their emissions exceeded U.S. emissions by 50 percent in 2012 (Olivier, Janssens-Maenhout, and Peters 2012).

Climate change is defined by many of the issues raised in section 2, and each of the potential barriers to optimal policy are even greater than they are for conventional pollutants. In the climate case, production and consumption choices generate global externalities ($e = e_0 + \sum_{i=1}^{n}(\Delta e_i + a(c_i, s_i))$, rather than just externalities across households in the same city, region, or even country. Further, the benefits of mitigation are both uncertain and in the future. The result is that any one actor has little incentive to curb growth in the name of mitigation and no single government or entity has authority over all emitters. In these respects, climate change is the standard problem of externalities and public goods on steroids.

This paper's four explanations for the poor state of environmental quality in developing countries all pose serious challenges to any global effort to significantly limit climate change. First, developing countries are likely to place a relatively low present value on current greenhouse reductions. This is because the marginal utility of current consumption in these countries is very high, relative to the marginal utility of future consumption, due to their low income levels and fast rates of growth. Further, today's developed countries are richer than the developing ones and experiencing slower growth, which means they are likely to place a higher value on current greenhouse gas reductions. Thus, both the high current marginal utility of consumption in developing countries and the difference in the marginal rates of substitution between current and future consumption make it challenging for rich and poor countries to find common ground on the value of carbon reductions, at least without substantial transfers that have their own political challenges (Becker et al. 2011; Deshpande and Greenstone 2011). Second, the marginal costs of reducing greenhouse gas emissions are substantial. In the transportation sector, there is not currently a viable large-scale alternative to petroleum, and in the electricity sector, recent estimates suggest that the private costs of zero carbon sources of electricity can be two-to-three times more expensive than electricity generated from fossil fuels (Greenstone and Looney 2012).

Slowing climate change may be difficult even without distortions to social welfare maximization, yet the distortions discussed above are highly relevant. With respect to the third explanation, political economy and rent-seeking forces can easily undermine efforts to reduce greenhouse gas emissions. It is difficult to monitor carbon emissions, and this opens the door to claimed reductions that exceed actual reductions. Indeed, the market for carbon offsets has been greatly undermined by overstated claims about impacts. Finally, a series of market failures may distort revealed $MWTP_e$ for carbon reductions in developing countries. For example, incomplete credit markets restrict opportunities to engage in long-term mitigation projects and incomplete insurance markets complicate efforts to protect oneself from uncertain climate damages. Furthermore, climate change seems almost to have been conceived by behavioral economists as an ideal setting for behavioral biases; it involves low probability events, impacts that are in the future, and trade-offs between current and future generations. There is substantial opportunity for important research about the roles of each of these four explanations in shaping climate mitigation policies.

It is against this background that research on the impacts of climate change and opportunities for adaptation have begun to emerge. A growing literature aims to estimate the likely economic impacts of climate change and shows projected increases in agricultural losses, storm damages, civil conflicts, and morbidity and mortality rates (Burke et al. forthcoming; Deschênes, Greenstone, and Guryan 2009; Deschênes and Greenstone 2011; Feng, Krueger, and Oppenheimer 2010; Feng, Oppenheimer, and Schlenker 2012; Schlenker and Lobell 2010; Graff Zivin and Neidell 2014; IPCC 2001). The available evidence indicates these losses are all likely to be of a greater magnitude in developing countries, where the resources available for investment in self-protection (adaptation) are limited. For example, Burgess et al. (2011) provide evidence that climate change may sharply reduce agricultural yields and increase mortality rates in rural India. They also compare results from rural areas to urban areas and to developed countries to show that those with opportunities for self-protection are able to mitigate the negative health impacts.

A recent line of research indicates that that adaptation does occur, but not without its own drawbacks. Interestingly, air conditioners can play a significant role in moderating the effects of extreme weather on mortality (Barreca et al. 2013; Graff Zivin, Hsiang, and Neidell 2013). However, they are often run with CO_2 intensive electricity and do little to protect against other climate-related risks such as storm frequency. For example, Davis and Gertler (2013) document the relationship between temperature and energy consumption in Mexico, and show that long-term weather patterns drive air conditioner adoption. Additionally, areas that experience more regular storms appear to experience less damage than do less well-adapted places when hit by comparable events, though adaptation is never sufficient to shrink damages to zero (Hsiang and Narita 2012; Anttila-Hughes and Hsiang 2012). Farmers also appear able to adapt to changes in climate, with some evidence from extended periods of drought that may better approximate the effects of climate change than studies that rely on short-run weather shocks. By adjusting both crop choice and land under irrigation, farmers in India mitigate losses due drought, however, only 14 percent of the substantial decline in profits are offset through adaptation (Taraz 2012). Moreover, migration may also offer a viable adaptation strategy (Boustan, Kahn, and Rhode 2012), though external migration incentives may be necessary even when the costs of not moving are very high (Bryan, Chowdhury, and Mobarak 2014).

Evidence to date suggests that climate change is already underway and that adaptation has begun. The considerable economic and political challenges to global mitigation programs underscore that there is a great need for new research that better quantifies the likely costs of climate change and that identifies and assesses the efficiency of potential mitigation and adaptation strategies. Beyond the societal value, this research has the potential to improve understanding about economic behavior more broadly.

5. *Discussion and Conclusion*

The intersection of environmental and development economics offers a wealth of questions that are of interest to economists and policymakers. What is the effect of environmental quality on economic development in developing countries? On health? On productivity? How do economic development and changing patterns of consumption and governance affect environmental quality? What are the political-economy factors that shape this relationship?

Many of these questions are poorly understood, and our aim in this article has been to highlight a framework for research in the emerging field of envirodevonomics. Our conceptual framework offers one approach to considering a fundamental puzzle: If environmental quality is so bad in developing countries, then why is $MWTP_e$ seemingly so low? Is it because, for the very poor, the marginal utility of consumption dominates utility gains from improved environmental quality, or because abatement costs are high? Or is $MWTP_e$ high, yet policy makers fail to express the preferences of their constituents in policy design and implementation? Alternatively, is it because the market failures that are so prevalent in developing countries also distort revealed $MWTP_e$?

The empirical literature summarized in section 3 suggests that all of these explanations may be at play, however further research is necessary to answer these questions definitively, noting that the answers may vary across settings. In the remainder of the conclusion, we outline some areas where we believe additional research would be particularly valuable.

1. What is the $MWTP_e$ for environmental quality and what factors determine this?

   (a) How much are people willing to pay for improvements in environmental quality in developing countries?

   (b) How are their valuations affected by the presence of market failures, poor information, weak governance and property rights, multiple risks, and poor policy design, weak implementation, and rent seeking?

   (c) How do peoples' decision heuristics and biases affect their willingness to use improved resources or technologies?

   (d) How do policies targeting adoption of environmentally friendly technologies, such as access to credit for energy efficiency investments, affect individuals' and firms' decisions?

   (e) Does a reduction in one environmental risk increase or decrease the value of environmental quality? Can an "O-ring" style model explain environmental decision making in developing countries?

   (f) Does worse environmental quality increase the variability of income? Do vulnerable groups use natural resources as a source of insurance?

2. What are the costs and benefits of policies to improve environmental quality and access to energy?
   (a) How large are the health benefits that result from improvements in water and air quality? Which programs achieve these benefits most cost-effectively?
   (b) Can providing information to the public change their behavior and exposure to environmental risks?
   (c) What factors determine whether environmental regulations are effective in developing countries?
   (d) How do issues of corruption and a government's capacity to enforce regulation influence the impact of specific environmental policies?
   (*e*) How much are people willing to pay for access to reliable energy sources? Or for reliable clean energy sources?
3. What policies can be effective for climate mitigation and adaptation?
   (a) How do the costs of abating a ton of carbon emissions compare across different policies?
      i) What is the cost of abating a ton of carbon through energy-efficient investments for consumers?
      ii) What is the cost through energy-efficiency policies targeting manufacturers, especially small- and medium-sized ones?
      iii) What is the cost of abating a ton of carbon through payments for ecosystem services?
      iv) Through market-based emissions trading systems?
   (b) What factors or design elements cause people in developing countries to make energy-efficiency investments?
   (c) Do transfers of funds or technologies from developed countries crowd out developing country investments in mitigation and adaptation?
   (d) Will clean-energy products that work in the lab have the same results when real people use them in real world settings?
   (e) What programs or policies can best protect vulnerable populations, like children, the elderly, and smallholder farmers, against the effects climate change?

These and many other topics are increasingly feasible areas for economic research, as data quality and availability improve. But even more importantly, finding reliable answers to these questions will advance economic understanding and inform policy, with the potential to enormously impact human welfare.

References

Acemoglu, Daron, Philippe Aghion, Leonardo Bursztyn, and David Hemous. 2012. "The Environment and Directed Technical Change." *American Economic Review* 102 (1): 131–66.

Ali, Daniel Ayalew, Klaus Deininger, and Markus Goldstein. 2014. "Environmental and Gender Impacts of Land Tenure Regularization in Africa: Pilot Evidence from Rwanda." *Journal of Development Economics* 110: 262–75.

Alix-Garcia, Jennifer, Craig McIntosh, Katharine R. E. Sims, and Jarrod R. Welch. 2013. "The Ecological Footprint of Poverty Alleviation: Evidence from Mexico's Opportunidades Program." *Review of Economics and Statistics* 95 (2): 417–35.

Alix-Garcia, Jennifer M., Katharine R. E. Sims, and Patricia Yañez-Pagans. Forthcoming. "Only One Tree from Each Seed? Environmental Effectiveness and Poverty Alleviation in Mexico's Payments for Ecosystem Services Program." *American Economic Journal: Economic Policy*.

Almond, Douglas, Yuyu Chen, Michael Greenstone, and Hongbin Li. 2009. "Winter Heating or Clean Air? Unintended Impacts of China's Huai River Policy." *American Economic Review* 99 (2): 184–90.

Andam, Kwaw S., Paul J. Ferraro, Katharine R. E. Sims, Andrew Healy, and Margaret B. Holland. 2010. "Protected Areas Reduced Poverty in Costa Rica and Thailand." *Proceedings of the National Academy of Sciences* 107 (22): 9996–10001.

Andreoni, James, and Arik Levinson. 2001. "The Simple Analytics of the Environmental Kuznets Curve." *Journal of Public Economics* 80 (2): 269–86.

Anttila-Hughes, Jesse K., and Solomon M. Hsiang. 2012. "Destruction, Disinvestment, and Death: Economic and Human Losses Following Environmental Disaster." Unpublished.

Aragón, Fernando M., and Juan Pablo Rud. 2013. "Modern Industries, Pollution and Agricultural Productivity: Evidence from Ghana." Unpublished.

Arceo-Gomez, Eva O., Rema Hanna, and Paulina Oliva. 2012. "Does the Effect of Pollution on Infant Mortality Differ between Developing and Developed Countries? Evidence from Mexico City." National Bureau of Economic Research Working Paper 18349.

Arriagada, Rodrigo A., Paul J. Ferraro, Erin O. Sills, Subhrendu K. Pattanayak, and Silvia Cordero-Sancho. 2012. "Do Payments for Environmental Services Affect Forest Cover? A Farm-Level Evaluation from Costa Rica." *Land Economics* 88 (2): 382–99.

Ashraf, Nava, James Berry, and Jesse M. Shapiro. 2010. "Can Higher Prices Stimulate Product Use? Evidence from a Field Experiment in Zambia." *American Economic Review* 100 (5): 2383–413.

Ashraf, Nava, B. Kelsey Jack, and Emir Kamenica. 2013. "Information and Subsidies: Complements or Substitutes?" *Journal of Economic Behavior and Organization* 88: 133–39.

Assunção, Juliano, Clarissa Gandour, Romero Rocha, and Rudi Rocha. 2013. "Does Credit Affect Deforestation? Evidence from a Rural Credit Policy in the Brazilian Amazon." Unpublished.

Banerjee, Abhijit, and Sendhil Mullainathan. 2010. "The Shape of Temptation: Implications for the Economic Lives of the Poor." National Bureau of Economic Research Working Paper 15973.

Barbier, Edward B. 2007. *Natural Resources and Economic Development*. Cambridge and New York: Cambridge University Press.

Bardhan, Pranab. 2002. "Decentralization of Governance and Development." *Journal of Economic Perspectives* 16 (4): 185–205.

Bardhan, Pranab, and Christopher Udry. 1999. *Development Microeconomics*. Oxford and New York: Oxford University Press.

Barreca, Alan, Karen Clay, Olivier Deschenes, Michael Greenstone, and Joseph S. Shapiro. 2013. "Adapting to Climate Change: The Remarkable Decline in the U.S. Temperature–Mortality Relationship over the 20th Century." National Bureau of Economic Research Working Paper 18692.

Baumol, William J., and Wallace E. Oates. 1988. *The Theory of Environmental Policy*, Second edition. Cambridge and New York: Cambridge University Press.

Becker, Gary S., Kevin M. Murphy, and Robert H. Topel. 2011. "On the Economics of Climate Policy." *B.E. Journal of Economic Analysis and Policy* 10 (2).

Bennear, Lori, Alessandro Tarozzi, Alexander Pfaff, Soumya Balasubramanya, Kazi Matin Ahmed, and Alexander van Geen. 2013. "Impact of a Randomized Controlled Trial in Arsenic Risk Communication on Household Water-Source Choices in Bangladesh." *Journal of Environmental Economics and Management* 65 (2): 225–40.

Bennett, Daniel. 2012. "Does Clean Water Make You Dirty? Water Supply and Sanitation in the Philippines." *Journal of Human Resources* 47 (1): 146–73.

Berry, James, Greg Fischer, and Raymond Guiteras. 2011. "Eliciting and Utilizing Willingness to Pay: Evidence from Field Trials in Northern Ghana." Unpublished.

Bertrand, Marianne, Sendhil Mullainathan, and Eldar Shafir. 2004. "A Behavioral-Economics View of Poverty." *American Economic Review* 94 (2): 419–23.

Besley, Timothy, and Torsten Persson. 2013. "Taxation and Development." In *Handbook of Public Economics, Volume 5*, edited by Alan J. Auerbach, Raj Chetty, Martin Feldstein, and Emmanuel Saez, 51–110. Amsterdam and Boston: Elsevier, North-Holland.

Bhattacharya, Soma, Anna Alberini, and Maureen L. Cropper. 2007. "The Value of Mortality Risk Reductions in Delhi, India." *Journal of Risk and Uncertainty* 34 (1): 21–47.

Boomhower, Judson, and Lucas W. Davis. 2014. "A Credible Approach for Measuring Inframarginal Participation in Energy Efficiency Programs." *Journal of Public Economics* 113: 67–79.

Boustan, Leah Platt, Matthew E. Kahn, and Paul W. Rhode. 2012. "Moving to Higher Ground: Migration Response to Natural Disasters in the Early Twentieth Century." *American Economic Review* 102 (3): 238–44.

Brainerd, Elizabeth, and Nidhiya Menon. 2014. "Seasonal Effects of Water Quality: The Hidden Costs of the Green Revolution to Infant and Child Health in India." *Journal of Development Economics* 107: 49–64.

Bryan, Gharad, Shyamal Chowdhury, and Ahmed Mushfiq Mobarak. 2014. "Underinvestment in a Profitable Technology: The Case of Seasonal Migration in

Bangladesh." *Econometrica* 82 (5): 1671–1748.

Bryan, Gharad, Dean Karlan, and Scott Nelson. 2010. "Commitment Devices." *Annual Review of Economics* 2: 671–98.

Burgess, Robin, Olivier Deschenes, Dave Donaldson, and Michael Greenstone. 2011. "Weather and Death in India." Unpublished.

Burgess, Robin, Matthew Hansen, Benjamin A. Olken, Peter Potapov, and Stefanie Sieber. 2012. "The Political Economy of Deforestation in the Tropics." *Quarterly Journal of Economics* 127 (4): 1707–54.

Burke, Marshall, John Dykema, David Lobell, Edward Miguel, and Shanker Satyanath. Forthcoming. "Incorporating Climate Uncertainty into Estimates of Climate Change Impacts, with Applications to U.S. and African Agriculture." *Review of Economics and Statistics*.

Cao, Jing, Richard Garbaccio, and Mun S. Ho. 2009. "China's 11th Five-Year Plan and the Environment: Reducing SO_2 Emissions." *Review of Environmental Economics and Policy* 3 (2): 231–50.

Carroll, Gabriel D., James J. Choi, David Laibson, Brigitte C. Madrian, and Andrew Metrick. 2009. "Optimal Defaults and Active Decisions." *Quarterly Journal of Economics* 124 (4): 1639–74.

Chay, Kenneth Y., and Michael Greenstone. 2003. "The Impact of Air Pollution on Infant Mortality: Evidence from Geographic Variation in Pollution Shocks Induced By a Recession." *Quarterly Journal of Economics* 118 (3): 1121–67.

Chen, Yuyu, Avraham Ebenstein, Michael Greenstone, and Hongbin Li. 2013. "Evidence on the Impact of Sustained Exposure to Air Pollution on Life Expectancy from China's Huai River Policy." *Proceedings of the National Academy of Sciences* 110 (32): 12936–41.

Chen, Yuyu, Ginger Zhe Jin, Naresh Kumar, and Guang Shi. 2012. "Gaming in Air Pollution Data? Lessons from China." *B.E. Journal of Economic Analysis and Policy* 12 (3).

Coase, Ronald H. 1960. "The Problem of Social Cost." *Journal of Law and Economics* 3: 1–44.

Conley, Timothy G., and Christopher R. Udry. 2010. "Learning about a New Technology: Pineapple in Ghana." *American Economic Review* 100 (1): 35–69.

Conning, Jonathan, and Christopher Udry. 2007. "Rural Financial Markets in Developing Countries." In *Handbook of Agricultural Economics, Volume 3: Agricultural Development: Farmers, Farm Production and Farm Markets*, edited by Robert Evenson and Prabhu Pingali, 2857–2908. Amsterdam and Oxford: Elsevier, North-Holland.

Copeland, Brian R., and M. Scott Taylor. 2005. *Trade and the Environment: Theory and Evidence*. Princeton and Oxford: Princeton University Press.

Cornes, Richard, and Todd Sandler. 1996. *The Theory of Externalities, Public Goods and Club Goods*, Second edition. Cambridge and New York: Cambridge University Press.

Currie, Janet, and Matthew Neidell. 2005. "Air Pollution and Infant Health: What Can We Learn from California's Recent Experience?" *Quarterly Journal of Economics* 120 (3): 1003–30.

Currie, Janet, and Reed Walker. 2011. "Traffic Congestion and Infant Health: Evidence from E-ZPass." *American Economic Journal: Applied Economics* 3 (1): 65–90.

Dasgupta, Partha. 2010. "The Place of Nature in Economic Development." In *Handbook of Development Economics, Volume 5*, edited by Dani Rodrik and Mark Rosenzweig, 4977–5046. Amsterdam and San Diego: Elsevier, North-Holland.

Dasgupta, Partha, and Karl-Göran Mäler. 1991. "The Environment and Emerging Development Issues." In *Proceedings of the World Bank Annual Conference on Development Economics 1990*, edited by Stanley Fischer, Dennis de Tray, and Shekhar Shah, 101–32. Washington, D.C.: World Bank Press.

Dasgupta, Partha, and Karl-Göran Mäler, eds. 1997. *The Environment and Emerging Development Issues, Volume 1*. Oxford: Clarendon Press.

Dasgupta, Partha, and Karl-Göran Mäler, eds. 2000. *The Environment and Emerging Development Issues, Volume 2*. Oxford: Clarendon Press.

Dasgupta, Susmita, Benoit Laplante, Hua Wang, and David Wheeler. 2002. "Confronting the Environmental Kuznets Curve." *Journal of Economic Perspectives* 16 (1): 147–68.

Dasgupta, Susmita, Robert E. B. Lucas, and David Wheeler. 1998. "Small Manufacturing Plants, Pollution and Poverty: New Evidence from Brazil and Mexico." World Bank Policy Research Working Paper 2029.

Davis, Lucas W. 2008. "The Effect of Driving Restrictions on Air Quality in Mexico City." *Journal of Political Economy* 116 (1): 38–81.

Davis, Lucas W., Alan Fuchs, and Paul Gertler. Forthcoming. "Cash for Coolers: Evaluating a Large-Scale Appliance Replacement Program in Mexico." *American Economic Journal: Economic Policy*.

Davis, Lucas W., and Paul Gertler. 2013. "The Central Role of Air Conditioning in the Relationship between Climate and Energy Use." Unpublished.

de Janvry, Alain, Marcel Fafchamps, and Elisabeth Sadoulet. 1991. "Peasant Household Behaviour with Missing Markets: Some Paradoxes Explained." *Economic Journal* 101 (409): 1400–1417.

Deschênes, Olivier, and Michael Greenstone. 2011. "Climate Change, Mortality, and Adaptation: Evidence from Annual Fluctuations in the US." *American Economic Journal: Applied Economics* 3 (4): 152–85.

Deschenes, Olivier, Michael Greenstone, and Jonathan Guryan. 2009. "Climate Change and Birth Weight." *American Economic Review* 99 (2): 211–17.

Deshpande, Manasi, and Michael Greenstone. 2011. "Comment on 'On the Economics of Climate Policy': Is Climate Change Mitigation the Ultimate Arbitrage Opportunity?" *B. E. Journal of Economic Analysis and Policy* 10 (2).

Devoto, Florencia, Esther Duflo, Pascaline Dupas, William Parienté, and Vincent Pons. 2012. "Happiness on Tap: Piped Water Adoption in Urban Morocco." *American Economic Journal: Economic Policy* 4 (4): 68–99.

Dinkelman, Taryn. 2011. "The Effects of Rural Electrification on Employment: New Evidence from South Africa." *American Economic Review* 101 (7): 3078–3108.

Dominici, Francesca, Michael Greenstone, and Cass R. Sunstein. 2014. "Particulate Matter Matters." *Science* 344 (6181): 257–59.

Duflo, Esther. 2012. "Human Values and the Design of the Fight against Poverty." Tanner Lectures on Human Values at Harvard University.

Duflo, Esther, Michael Greenstone, Raymond Guiteras, and Thomas Clasen. 2014. "The Short- and Medium-Run Impact of Clean Water and Sanitation on Diarrhea in Rural India." Unpublished.

Duflo, Esther, Michael Greenstone, Rohini Pande, and Nicholas Ryan. 2013. "Truth-Telling By Third-Party Auditors and the Response of Polluting Firms: Experimental Evidence from India." *Quarterly Journal of Economics* 128 (4): 1499–1545.

Duflo, Esther, and Rohini Pande. 2007. "Dams." *Quarterly Journal of Economics* 122 (2): 601–46.

Dupas, Pascaline. 2011. "Health Behavior in Developing Countries." *Annual Review of Economics* 3: 425–49.

Ebenstein, Avraham. 2012. "The Consequences of Industrialization: Evidence from Water Pollution and Digestive Cancers in China." *Review of Economics and Statistics* 94 (1): 186–201.

Feler, Leo, and J. Vernon Henderson. 2011. "Exclusionary Policies in Urban Development: Under-Servicing Migrant Households in Brazilian Cities." *Journal of Urban Economics* 69 (3): 253–72.

Feng, Shuaizhang, Alan B. Krueger, and Michael Oppenheimer. 2010. "Linkages among Climate Change, Crop Yields and Mexico–US Cross-Border Migration." *Proceedings of the National Academy of Sciences* 107 (32): 14257–62.

Feng, Shuaizhang, Michael Oppenheimer, and Wolfram Schlenker. 2012. "Climate Change, Crop Yields, and Internal Migration in the United States." National Bureau of Economic Research Working Paper 17734.

Ferraro, Paul J., Kathleen Lawlor, Katrina L. Mullan, and Subhrendu K. Pattanayak. 2012. "Forest Figures: Ecosystem Services Valuation and Policy Evaluation in Developing Countries." *Review of Environmental Economics and Policy* 6 (1): 20–44.

Field, Erica, Rachel Glennerster, and Reshmaan Hussam. 2011. "Throwing the Baby Out with the Drinking Water: Unintended Consequences of Arsenic Mitigation Efforts in Bangladesh." Unpublished.

Fischer, Carolyn, and Garth Heutel. 2013. "Environmental Macroeconomics: Environmental Policy, Business Cycles, and Directed Technical Change." *Annual Review of Resource Economics* 5: 197–210.

Fisman, Raymond. 2001. "Estimating the Value of Political Connections." *American Economic Review* 91 (4): 1095–1102.

Foster, Andrew, and Emilio Gutierrez. 2012. "Direct and Indirect Effects of Voluntary Certification: Evidence from the Mexican Clean Industry Program." Unpublished.

Foster, Andrew, Emilio Gutierrez, and Naresh Kumar. 2009. "Voluntary Compliance, Pollution Levels, and Infant Mortality in Mexico." *American Economic Review* 99 (2): 191–97.

Foster, Andrew D., and Mark R. Rosenzweig. 1995. "Learning By Doing and Learning from Others: Human Capital and Technical Change in Agriculture." *Journal of Political Economy* 103 (6): 1176–1209.

Foster, Andrew D., and Mark R. Rosenzweig. 2010. "Microeconomics of Technology Adoption." *Annual Review of Economics* 2: 395–424.

Fowlie, Meredith L. 2009. "Incomplete Environmental Regulation, Imperfect Competition, and Emissions Leakage." *American Economic Journal: Economic Policy* 1 (2): 72–112.

Fowlie, Meredith L. 2010. "Emissions Trading, Electircity Restructuring, and Investment in Pollution Abatement." *American Economic Review* 100 (3): 837–69.

Fowlie, Meredith L., Christopher R. Knittel, and Catherine Wolfram. 2012. "Sacred Cars? Cost-Effective Regulation of Stationary and Nonstationary Pollution Sources." *American Economic Journal: Economic Policy* 4 (1): 98–126.

Galiani, Sebastian, Paul Gertler, and Ernesto Schargrodsky. 2005. "Water for Life: The Impact of the Privatization of Water Services on Child Mortality." *Journal of Political Economy* 113 (1): 83–120.

Gallego, Francisco, Juan-Pablo Montero, and Christian Salas. 2013. "The Effect of Transport Policies on Car Use: Evidence from Latin American Cities." *Journal of Public Economics* 107: 47–62.

Gertler, Paul, Orie Shelef, Catherine Wolfram, and Alan Fuchs. 2013. "How Pro-Poor Growth Affects the Demand for Energy." National Bureau of Economic Research Working Paper 19092.

Graff Zivin, Joshua S., S. Hsiang, and Matthew Neidell. 2013. "Climate, Human Capital and Adaptation." Unpublished.

Graff Zivin, Joshua, and Matthew Neidell. 2014. "Temperature and the Allocation of Time: Implications for Climate Change." *Journal of Labor Economics* 32 (1): 1–26.

Greenstone, Michael, and Rema Hanna. 2014. "Environmental Regulation, Air and Water Pollution, and Infant Mortality in India." *American Economic Review* 104 (10): 3038–72.

Greenstone, Michael, and Adam Looney. 2012. "Paying Too Much for Energy? The True Costs of Our Energy Choices." *Daedalus* 141 (2): 10–30.

Grossman, Gene M., and Alan B. Krueger. 1995. "Economic Growth and the Environment." *Quarterly Journal of Economics* 110 (2): 353–77.

Guiteras, Raymond, David I. Levine, Thomas H. Polley, and Brian Quistorff. 2014. "Credit Constraints, Discounting and Investment in Health: Evidence from Micropayments for Clean Water in Dhaka." Unpublished.

Hall, Robert E., and Charles I. Jones. 2007. "The Value of Life and the Rise in Health Spending." *Quarterly Journal of Economics* 122 (1): 39–72.

Hanna, Rema, and Paulina Oliva. 2014. "Moving Up the Energy Ladder: The Effect of an Increase in Economic Well-Being on Fuel Consumption Choices of the Poor in India." Unpublished.

Hanna, Rema, and Paulina Oliva. Forthcoming. "The Effect of Pollution on Labor Supply: Evidence from a Natural Experiment in Mexico City." *Journal of Public Economics*.

Harbaugh, William T., Arik Levinson, and David Molloy Wilson. 2002. "Reexamining the Empirical Evidence for an Environmental Kuznets Curve." *Review of Economics and Statistics* 84 (3): 541–51.

Hassan, Rashid, Robert Scholes, and Neville Ash, eds. 2005. *Ecosystem and Human Well-Being: Current State and Trends, Volume 1*. Washington and London: Island Press.

Hassler, John, and Per Krusell. 2012. "Economics and Climate Change: Integrated Assessment in a Multi-region World." *Journal of the European Economic Association* 10 (5): 974–1000.

Hemous, David. 2013. "Environmental Policy and Directed Technical Change in a Global Economy: The Dynamic Impact of Unilateral Environmental Policies." Centre for Economic Policy Research Discussion Paper 9733.

Henderson, Vernon, Adam Storeygard, and David N. Weil. 2011. "A Bright Idea for Measuring Economic Growth." *American Economic Review* 101 (3): 194–99.

Horowitz, John K. 1998. "Review of *The Environment and Emerging Development Issues. Volumes 1 and 2*." *Journal of Economic Literature* 36 (3): 1529–30.

Hsiang, Solomon M., and Daiju Narita. 2012. "Adaptation to Cyclone Risk: Evidence from the Global Cross-Section." *Climate Change Economics* 3 (2).

Hsieh, Chang-Tai, and Peter J. Klenow. 2009. "Misallocation and Manufacturing TFP in China and India." *Quarterly Journal of Economics* 124 (4): 1403–48.

Intergovernmental Panel on Climate Change. 2001. *Climate Change 2001: Impacts, Adaptation, and Vulnerability: Contribution of Working Group II to the Third Assessment Report of the Intergovernmental Panel on Climate Change*. Edited by James J. McCarthy et al. Cambridge and New York: Cambridge University Press.

Israel, Debra, and Arik Levinson. 2004. "Willingness to Pay for Environmental Quality: Testable Empirical Implications of the Growth and Environment Literature." *B. E. Journal of Economic Analysis and Policy* 3 (1).

Jack, B. Kelsey. 2013. "Private Information and the Allocation of Land Use Subsidies in Malawi." *American Economic Journal: Applied Economics* 5 (3): 113–35.

Jalan, Jyotsna, and E. Somanathan. 2008. "The Importance of Being Informed: Experimental Evidence on Demand for Environmental Quality." *Journal of Development Economics* 87 (1): 14–28.

Jayachandran, Seema. 2009. "Air Quality and Early-Life Mortality: Evidence from Indonesia's Wildfires." *Journal of Human Resources* 44 (4): 916–54.

Kahn, Matthew E., Pei Li, and Daxuan Zhao. Forthcoming. "Water Pollution Progress at Borders: The Role of Changes in China's Political Promotion Incentives." *American Economic Journal: Economic Policy*.

Kelly, David L., and Charles D. Kolstad. 1999. "Integrated Assessment Models for Climate Change Control." In *The International Yearbook of Environmental and Resource Economics 1999/2000: A Survey of Current Issues*, edited by Henk Folmer and Tom Tietenberg, 171–97. New York: Elgar.

Kremer, Michael. 1993. "The O-Ring Theory of Economic Development." *Quarterly Journal of Economics* 108 (3): 551–75.

Kremer, Michael, Jessica Leino, Edward Miguel, and Alix Peterson Zwane. 2011. "Spring Cleaning: Rural Water Impacts, Valuation, and Property Rights Institutions." *Quarterly Journal of Economics* 126 (1): 145–205.

Kumler, Todd, Eric Verhoogen, and Judith Frías. 2013. "Enlisting Workers in Monitoring Firms: Payroll Tax Compliance in Mexico." Working Paper.

Lemos, Maria Carmen, and Arun Agrawal. 2006. "Environmental Governance." *Annual Review of Environment and Resources* 31: 297–325.

León, Gianmarco, and Edward Miguel. 2012. "Transportation Choices, Fatalism and the Value of Life in Africa." Working Paper.

Lin, C.-Y. Cynthia, Wei Zhang, and Victoria I. Umanskaya. 2011. "On the Design of Driving Restrictions: Theory and Empirical Evidence." Working Paper.

Lipscomb, Molly. 2008. "The Effect of Environmental Enforcement on Product Choice and Competition: Theory and Evidence from India." Unpublished.

Lipscomb, Molly, and Ahmed Mushfiq Mobarak. 2011. "Decentralization and the Political Economy of Water Pollution: Evidence from the Re-drawing of County Borders in Brazil." Unpublished.

Lipscomb, Molly, Ahmed Mushfiq Mobarak, and Tania Barham. 2013. "Development Effects of Electrification: Evidence from the Topographic Placement of Hydropower Plants in Brazil." *American Economic Journal: Applied Economics* 5 (2): 200–231.

Lofgren, Asa, Peter Martinsson, Magnus Hennlock, and Thomas Sterner. 2012. "Are Experienced People Affected By a Pre-set Default Option—Results from a Field Experiment." *Journal of Environmental Economics and Management* 63 (1): 66–72.

Madajewicz, Malgosia, et al. 2007. "Can Information Alone Change Behavior? Response to Arsenic Contamination of Groundwater in Bangladesh." *Journal of Development Economics* 84 (2): 731–54.

McRae, Shaun. 2015. "Infrastructure Quality and the Subsidy Trap." *American Economic Review* 105, (1): 35–66.

Miller, Grant, and Ahmed Mushfiq Mobarak. 2013.

"Gender Differences in Preferences, Intra-household Externalities, and Low Demand for Improved Cookstoves." National Bureau of Economic Research Working Paper 18964.

Mullainathan, Sendhil. 2006. "Better Choices to Reduce Poverty." In *Understanding Poverty*, edited by Abjijit Vinayak Banerjee, Roland Benabou, and Dilip Mookherjee, 379–88. Oxford and New York: Oxford University Press.

Nordhaus, William D. 2013. "Integrated Economic and Climate Modeling." In *Handbook of Computable General Equilibrium Modeling, Volume 1*B, edited by Peter B. Dixon and Dale W. Jorgenson, 1069–1132. Amsterdam and Boston: Elsevier, North-Holland.

Oliva, Paulina. Forthcoming. "Environmental Regulations and Corruption: Automobile Emissions in Mexico City." *Journal of Political Economy*.

Olivier, Jos G. J., Greet Janssens-Maenhout, and Jeroen A. H. W. Peters. 2012. "Trends in Global CO_2 Emissions: 2012 Report." The Hague: PBL Netherlands Environmental Assessment Agency.

Olken, Benjamin A., and Rohini Pande. 2012. "Corruption in Developing Countries." *Annual Review of Economics* 4: 479–509.

Ostrom, Elinor. 2000. "Collective Action and the Evolution of Social Norms." *Journal of Economic Perspectives* 14 (3): 137–58.

Pattanayak, Subhrendu K., and Alexander Pfaff. 2009. "Behavior, Environment, and Health in Developing Countries: Evaluation and Valuation." *Annual Review of Resource Economics* 1: 183–217.

Pattanayak, Subhrendu K., et al. 2009. "Shame or Subsidy Revisited: Social Mobilization for Sanitation in Orissa, India." *Bulletin of the World Health Organization* 87 (8): 580–87.

Pitt, Mark M., Mark R. Rosenzweig, and Nazmul Hassan. 2010. "Short- and Long-Term Health Effects of Burning Biomass in the Home in Low-Income Countries." Unpublished.

Pitt, Mark M., Mark R. Rosenzweig, and Nazmul Hassan. 2012. "Identifying the Hidden Costs of a Public Health Success: Arsenic Well Water Contamination and Productivity in Bangladesh." Unpublished.

Pomeranz, Dina. 2013. "No Taxation without Information: Deterrence and Self-Enforcement in the Value Added Tax." National Bureau of Economic Research Working Paper 19199.

Robalino, Juan, and Alexander Pfaff. 2013. "Ecopayments and Deforestation in Costa Rica: A Nationwide Analysis of PSA's Initial Years." *Land Economics* 89 (3): 432–48.

Ryan, Nicholas. 2014. "The Competitive Effects of Transmission Infrastructure in the Indian Day-Ahead Electricity Market." Working Paper.

Ryan, Stephen P. 2012. "The Costs of Environmental Regulation in a Concentrated Industry." *Econometrica* 80 (3): 1019–61.

Schlenker, Wolfram, and David B. Lobell. 2010. "Robust Negative Impacts of Climate Change on African Agriculture." *Environmental Research Letters* 5 (1).

Sekhri, Sheetal. 2011. "Public Provision and Protection of Natural Resources: Groundwater Irrigation in Rural India." *American Economic Journal: Applied Economics* 3 (4): 29–55.

Shapiro, Joseph S. 2013. "Trade, CO2, and the Environment." Unpublished.

Shleifer, Andrei, and Robert W. Vishny. 2002. *The Grabbing Hand: Government Pathologies and Their Cures*. Cambridge, Mass. and London: Harvard University Press.

Shogren, Jason F., and Laura O. Taylor. 2008. "On Behavioral–Environmental Economics." *Review of Environmental Economics and Policy* 2 (1): 26–44.

Sigman, Hilary. 2002. "International Spillovers and Water Quality in Rivers: Do Countries Free Ride?" *American Economic Review* 92 (4): 1152–59.

Sims, Katharine R. E. 2010. "Conservation and Development: Evidence from Thai Protected Areas." *Journal of Environmental Economics and Management* 60 (2): 94–114.

Smith, V. Kerry. 2012. "Reflections—In Search of Crosswalks between Macroeconomics and Environmental Economics." *Review of Environmental Economics and Policy* 6 (2): 298–317.

Stern, David I. 2004. "The Rise and Fall of the Environmental Kuznets Curve." *World Development* 32 (8): 1419–39.

Stiglitz, Joseph E. 1989. "Markets, Market Failures, and Development." *American Economic Review* 79 (2): 197–203.

Szabo, Andrea. 2014. "The Value of Free Water: Analyzing South Africa's Free Basic Water Policy." Unpublished.

Taraz, Vis. 2012. "Adaptation to Climate Change: Historical Evidence from the Indian Monsoon." Unpublished.

United Nations. 2009. *State of the World's Indigenous Peoples*. New York: United Nations Publications.

United Nations Environment Programme. 2001. "The Well-Being of Nations." Global Environmental Monitoring System/Water Quality Monitoring System Technical Report.

U.S. Environmental Protection Agency, National Center for Environmental Economics. 2010. *Guidelines for Preparing Economic Analyses*. Washington, D.C.: U.S. Environmental Protection Agency.

Vennemo, Haakon, Kristin Aunan, Henrik Lindhjem, and Hans Martin Seip. 2009. "Environmental Pollution in China: Status and Trends." *Review of Environmental Economics and Policy* 3 (2): 209–30.

Viard, V. Brian, and Shihe Fu. 2011. "The Effect of Beijing's Driving Restrictions on Pollution and Economic Activity." Unpublished.

Viscusi, W. Kip, and Joseph E. Aldy. 2003. "The Value of a Statistical Life: A Critical Review of Market Estimates Throughout the World." *Journal of Risk and Uncertainty* 27 (1): 5–76.

Vohs, Kathleen D., Roy F. Baumeister, Brandon J. Schmeichel, Jean M. Twenge, Noelle M. Nelson, and Dianne M. Tice. 2008. "Making Choices Impairs

Subsequent Self-Control: A Limited-Resource Account of Decision Making, Self-Regulation, and Active Initiative." *Journal of Personality and Social Psychology* 94 (5): 883–98.

Wolfram, Catherine, Orie Shelef, and Paul Gertler. 2012. "How Will Energy Demand Develop in the Developing World?" *Journal of Economic Perspectives* 26 (1): 119–38.

World Health Organization. 2004. "Global Health Observatory Data Repository." Technical Report.

World Health Organization. 2011. "Database: Outdoor Air Pollution in Cities." Public Health and Environment Technical Report.

Zheng, Siqi, Cong Sun, Ye Qi, and Matthew E. Kahn. 2014. "The Evolving Geography of China's Industrial Production: Implications for Pollution Dynamics and Urban Quality of Life." *Journal of Economic Surveys* 28 (4): 709–24.