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A Research Agenda for a Young Field**

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# Envirodevonomics: A Research Agenda for a Young Field\*

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## Abstract

Environmental quality in many developing countries is poor and generates substantial health and productivity costs. However, existing measures of willingness to pay 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 WTP so low? We develop a conceptual framework for understanding this puzzle and propose four potential explanations: (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 policy-making, and (4) market failures such as weak property rights and missing capital markets drive a wedge between true and revealed willingness to pay for environmental quality. We review the available literature on each explanation and discuss how the framework also 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.”

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# 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 concentrations in urban centers, while the bottom panel shows dissolved oxygen, a measure of good water quality.<sup>1</sup> The developing countries are remarkably dirtier (higher particulates, lower dissolved oxygen).<sup>2</sup>

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.<sup>3</sup> On the other hand in spite of this large disease burden, the studies measuring willingness to pay (WTP) for environmental quality improvements indicate low valuations by affected households. For example, the value of a statistical life imputed from households' WTP for access to clean water in Kenya is USD2013 860, while typical VSL numbers from the United States are on the order of USD2013 8.6 million (US EPA 2010).<sup>4</sup>

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 WTP so low? Put another way, is the value of a life in Kenya, as suggested by the revealed preference data (Kremer et al. 2011), 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

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<sup>1</sup>Particulate matter comes both from primary sources (incomplete combustion, dust) and secondary reactions in the atmosphere. Particles smaller than 10 micrometers in diameter are typically associated with the greatest risk to human health. Dissolved oxygen is a proxy for organic waste, which requires oxygen for decomposition, in the water. Sources of organic waste include sewage and urban runoff (US EPA).

<sup>2</sup>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.

<sup>3</sup>Obtaining causal estimates of the health consequences of environmental quality is challenging. Randomized control trials are unethical in most 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.

<sup>4</sup>As the conceptual framework makes explicit, WTP includes not only the valuation of morbidity and mortality benefits of improved environmental quality (VSL), but also aesthetic and income benefits.

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 urgent 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 credible answers to these questions require the development of a new sub-field that is at the intersection of these two larger and more well established fields. At the risk of excessive reductionism, we argue that this sub-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. First and most obviously, environmental quality may be low because of low WTP for improvements. There are several possible causes of low WTP, including – most centrally – high marginal utility of consumption at low income levels. Second, high marginal costs of environmental quality improvements would also result in a lack of regulation to address 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 policy makers 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, WTP 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.<sup>5</sup>

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, and on the potential underlying causes of low WTP, marginal costs, political economy and market failures. Many papers have been written on these topics, but we focus attention on the relatively small set of papers that employ evaluation techniques that are likely to produce credible estimates of the underlying causal relationship or that open new areas of inquiry. One important theme in this section

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<sup>5</sup>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.

is that a confluence of events – 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 determination of key parameters – provide 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.

## 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 consider a representative agent with utility from consumption, environmental quality and health. The social planner aggregates agent preferences and maximizes net benefits by setting marginal benefits equal to marginal costs.<sup>6</sup> We explore four explanations for poor environmental quality: (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 agents’ WTP for environmental quality to diverge from their valuations in the first best. Note that the first two of these explanations require no deviation from the first best, 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.

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<sup>6</sup>Our approach in the conceptual framework therefore abstracts from important differences in the feasibility and costs of improving environmental quality through individual actions versus interventions at the state or federal level. We return to this issue when we discuss the marginal costs and political economy of environmental quality improvements.

## 2.1 Conceptual framework

We consider the WTP for environmental quality of a representative agent endowed with initial income  $y_0$ , initial health quality  $h_0$ , and initial environmental quality  $e_0$ . The agent chooses consumption  $c$ , improvements in environmental quality  $\Delta e$ , 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 income and environmental quality are defined by

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

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

and the function  $a(c, s)$  captures the impact of consumption and self protection on environmental quality as experienced by the agent.

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 environmental quality (equation 4), the model acknowledges that agents may affect environmental quality both directly, through  $\Delta e$ , and indirectly, through  $c$ . We model this as  $a(c, s)$  to highlight consumption geared toward self protection, such as air conditioning or bottled water, that create feedbacks between self protection, health and environmental quality. Most of the effects of consumption on

environmental quality are externalities, such that the privately felt impact  $a(c, s)$  is less than the social impact  $a^S(c, s)$ . To the extent that  $a(c, s) \neq a^S(c, s)$ , private optimization will not deliver the first best, and agents will, in most cases, over-consume.

In the first best, where  $a(c, s) = a^S(c, s)$ , the agent chooses  $\Delta e$ ,  $s$  and  $c$  to equalize the marginal utility of these investments. Willingness to pay is therefore the marginal benefit of environmental quality or the marginal rate of substitution between income and environmental quality.

$$MB = WTP_e = \frac{\frac{\partial U}{\partial e} + \frac{\partial U}{\partial h} \frac{\partial h}{\partial e}}{\frac{\partial U}{\partial c} + \frac{\partial U}{\partial e} \frac{\partial e}{\partial c}} + \frac{\partial \Delta y}{\partial e} + \frac{\partial \Delta y}{\partial h} \frac{\partial h}{\partial e} \quad (5)$$

The marginal benefit function expresses in dollars how much the agent will be willing to pay for a marginal increase in environmental quality. Willingness to pay is composed of the aesthetic benefit from improved environmental quality (scaled by the marginal utility of consumption), the indirect benefit of environmental quality for health (again scaled by the  $MU$  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.<sup>7</sup>

Similarly we can also calculate WTP for self protection  $s$ :

$$WTP_s = \frac{\frac{\partial U}{\partial e} \frac{\partial a}{\partial s} + \frac{\partial U}{\partial h} \frac{\partial h}{\partial s}}{\frac{\partial U}{\partial c} + \frac{\partial U}{\partial e} \frac{\partial e}{\partial c}} + \frac{\partial \Delta y}{\partial h} \frac{\partial h}{\partial s} \quad (6)$$

The WTP for self-protection is composed of the indirect effect of self protection on environmental quality ( $\frac{\partial U}{\partial e} \frac{\partial a}{\partial s}$ ), as well as the indirect effect of self protection on health ( $\frac{\partial U}{\partial h} \frac{\partial h}{\partial s}$ ). If the marginal utility of consumption is concave, then  $WTP_s$  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 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

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<sup>7</sup>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).

environmental quality.

In this first best environment, the social planner aggregates utility to arrive at a social welfare function. In the framework above, the marginal cost of improving environmental quality is  $c'_e(\Delta e)$  and the marginal cost of self protection is  $c'_s(s)$ . The social planner will therefore set the marginal costs of environmental quality improvements and of self protection equal to their respective marginal benefits, such that the ratios are equal to each other:

$$\frac{MB_e}{MB_s} = \frac{c'_e(\Delta e)}{c'_s(s)} \quad (7)$$

It is straightforward to incorporate the two deviations from the first best that we consider – political economy and market failures – as additional elements in the social planner’s problem. We now turn to four explanations for poor environmental quality in developing countries, including discussions of these two possible deviations from the first best.

## 2.2 Explanation 1: High marginal utility of consumption

We begin with the straightforward explanation that WTP is low because people are poor and therefore the marginal utility of consumption is high relative to the marginal utility of environmental quality. This explanation requires no deviation from the first best assumptions, and measured WTP accurately reflects preferences under a very tight budget constraint. This is straightforward to see in the comparative statics of our framework. 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 concave, then the agent is most likely to forgo investments in environmental quality in favor of consumption at low levels of consumption. For example, even if improvements in environment 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) that an agent experiences from an increase in consumption.

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 WTP for environmental quality will increase with income. Because later period consumption is increasing in income, and the marginal utility of consumption is decreasing, WTP for environmental quality 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.

### **2.3 Explanation 2: High marginal costs**

Without departing from assumptions of the first best, high marginal costs of providing environmental quality can explain the observed poor quality in developing countries. Even in contexts with high WTP and a benevolent social planner, high marginal costs are sufficient to make improvements to environmental quality inefficient, as shown by 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 are not necessarily driven by abatement costs alone; they also reflect capacity for policy design and implementation. In settings where either or both are weak, the marginal cost of environmental quality improvement may be high even if marginal abatement costs are relatively low. Alternatively, low marginal cost 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 to be 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. Peltzman-style compensatory behavior may be especially likely in settings where the public provision of environmental quality exceeds the socially optimal level (Peltzman 1975).

### **2.4 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 WTP 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 optimize according to the first best, 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 benefits over which the social planner optimizes.

## 2.5 Explanation 4: Measured WTP may not measure true WTP

While the relationship between income and WTP for environmental quality can explain a valuation gap between rich and poor countries, revealed preference measures of WTP may not equal WTP in the first best, due to market failures or behavioral heuristics and biases. In our conceptual framework, market failures, both from public goods and externalities and from the institutional failures present in many developing countries, result in marginal benefits from environmental quality improvements ( $MB'$ ) that do not equal the first best marginal benefit ( $MB^*$ ). A social planner who observes only revealed preferences may choose a level of environmental quality that is suboptimal because it is based on  $MB'$  rather than  $MB^*$ . If the cost of moving from  $MB'$  to  $MB^*$  is less than the improvement in social welfare, then correcting the market failure can lead to a Pareto improvement.

### 2.5.1 Public goods and externalities

Environmental economics is a field built on studying the market failures associated with public goods and externalities (Baumol and Oates 1988). In these situations, each agent's choice of  $\Delta e$  affects the utility of other agents, and because of these externalities, agents do not make socially efficient investments in  $\Delta e$ . We can see this in the context of our conceptual framework by allowing the private and social costs of consumption to diverge:  $a(c, s) > a^S(c, s)$ . The first term in the expression for WTP for environmental quality (equation 5) is decreasing in the second term in the denominator, which we can assume to be negative in the case of negative externalities from consumption. If agents undervalue these negative externalities, then they will also reveal a WTP for environmental quality that is below the first best. More simply, if an investment in  $\Delta e$  generates positive externalities, these will not enter into the agent's optimization problem, further lowering WTP for environmental quality.

A social planner who aggregates across agents will, of course, internalize many of these externalities, to the extent that they fall within her jurisdiction. Generally, the public goods nature of environmental quality does not differ substantially between developed and developing countries but, as we detail below, externalities may be exacerbated by and interact

with other market failures that are more prevalent in developing country settings.

### 2.5.2 Market failures from development economics

The classic market failures of developing economies may have important implications for observed WTP for environmental quality 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 when information, credit, risk, or land markets are imperfect, then the WTP for environmental quality that maximizes utility can be distorted away from the first best due to these imperfections. Furthermore, these different types of market failures may interact in complicated ways that can make an otherwise efficient correction (e.g., a Pigouvian tax) to one market failure suboptimal in the presence of others (e.g., weak property rights). These market failures 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 WTP for environmental quality. For these market failures, whether revealed WTP ( $MB'$ ) is above or below  $MB^*$  is theoretically ambiguous.

Revealed preference measures of WTP 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. Mis-information 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  $MB'$  measures below their full-information preferences ( $MB^*$ ).

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. The result is that estimates of WTP for environmental quality may be confounded with liquidity constraints.

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 may increase agents' WTP to avoid these added risks. Furthermore, if an agent faces multiple environmental or health risks (such as both contaminated water and polluted air), the WTP to improve quality of one environmental factor may be affected by the endowment of the other environmental factor. In an "O-ring" style model, WTP can be driven to zero in the presence of numerous environmental risks (Kremer 1993). Alternatively one environmental good might be a substitute for another such that WTP for one good decreases with the endowment of the other one.

Consider also the example of imperfect land markets or poorly defined property rights. Weak land tenure may lower WTP for environmental quality investments, 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 WTP will be below the first best because of weak property rights.

### **2.5.3 Behavioral heuristics and cognitive biases**

Numerous behavioral and cognitive biases are likely to affect revealed preference measures of WTP for environmental quality (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 et al. 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 exacerbate the distortions on revealed preference WTP measures in the presence of market or government failures.

### 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 (see, for a review, Dasgupta (2009)). However, we believe that a confluence of trends has created the conditions necessary for a new literature to bloom that has the potential to inform the question of why environmental quality is so poor in developing countries. This section describes these trends and the opportunity they create. It then reviews the emerging 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 a review of the theory and macroeconomics research that is relevant to the intersection of environmental and development economics 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 literature 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 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 20th century in the US and Europe, but still highlights the extraordinary levels of pollution faced by Chinese citizens today.<sup>8</sup> 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,

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<sup>8</sup>See relevant articles in a recent *Review of Environmental Economics and Policy* special issue (e.g., Vennemo et al. 2009; Cao et al. 2009)

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.<sup>9</sup> As the studies below make clear, the greatest progress has been made in quantifying the impact of environmental quality on health ( $h(e)$ ), rather than the willingness to pay for such a change. In addition, the vast majority of studies related to willingness to pay have focused on health channels, rather than direct effects ( $U'(e)$ ) or other indirect channels such as income ( $\Delta y'(e)$ ). Presumably, this is largely due to the challenges of measuring the relevant outcomes or of credibly identifying the effects of environmental quality on non-health 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 Greenstone and Hanna (2013)), 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 government officials have incentives to distort environmental data (e.g., Chen et al. (2013) on gaming of air quality data in China). Indeed, a growing number of papers rely on satellite imagery to measure outcomes including pollution (Foster et al. 2009; Jayachandran 2009), deforestation (Burgess et al. 2012; Alix-Garcia et al. 2013) and economic activity (Henderson et al. 2011). Others use geographic information system maps to generate instruments for development outcomes (Dufflo and Pande 2007; Dinkelman 2011; Lipscomb et al. 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

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<sup>9</sup>Potentially, but by no means exclusively, the ones laid out in Section 2.

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 et al. 2012). 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 et al. (2011); Duflo et al. (2012, 2013); Jack (2013); Kremer et al. (2011); Miller and Mobarak (2011); Benneer et al. (2012), 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.

We now turn to reviewing the existing literature.<sup>10</sup> Many relevant papers have been written, but due to space constraints we restrict ourselves to the relatively small set of papers that employ evaluation techniques especially likely to produce credible estimates of the underlying causal relationship or that open new areas of inquiry on environmental problems in developing countries.

### 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 translates 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 substantially compromises human health in these settings.

Many of the relevant studies focus on the health impacts of air pollution ( $h'(e)$ ). 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

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<sup>10</sup>See also review articles from the recent special issue on environmental quality and economic development in the *Review of Environmental Economics and Policy* (e.g., Vincent 2010; Pattanayak et al. 2010; Blackman 2010; Somanathan 2010).

rates: increasing the long-term exposure to TSPs by  $100 \mu\text{g}/\text{m}^3$  is associated with a decrease of 2.5 years of life expectancy. This estimate is larger than the effect measured in developed countries and is 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.

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 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 pre-natal exposure. A recent study by Arceo, 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  $1 \mu\text{g}/\text{m}^3$  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 U.S., while the impact of particulate matter on infant mortality is similar to or smaller than in the U.S.

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 (2012) 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. Duffo, Greenstone, Guiteras, and Clasen (2013) find that providing communal water tanks and private bathing 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.  $\Delta y'(e) > 0$ ). 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. In this case, the channel appears to be increased local revenue from tourism.

Indirect effects have been documented via productivity and health (i.e.  $\Delta y'(h(e))$ ). Using a difference in difference strategy, with additional variation in exposure from seasonal wind patterns, Hanna and Oliva (2011) 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 and Rosenzweig (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 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 non-health channels. All of these are promising areas for future research.

### 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 WTP. Instead, the studies reviewed in the previous subsection aim to describe  $h'(e)$  or  $\Delta y'(e, h)$ . However, the WTP or utility associated with these changes is the relevant parameter for the social planner (see equation 5) and central ingredient in the determination of optimal policy.

Few studies attempt to develop revealed preference estimates of WTP for environmental quality and/or health. 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 WTP 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.<sup>11</sup> In addition, the same households' revealed WTP is substantially lower than the valuations they give in a contingent valuation survey. Other studies that measure the WTP for health in developing countries may offer estimates of the appropriate valuation to assign to  $u'(h)$ . The empirical literature valuing improvements to health in developing countries is reviewed by Dupas (2011) and is consistent with WTP well below that in developed countries.

Overall, the available evidence suggests that  $WTP_e$  is low. It is an open question as to whether individuals' valuations are truly so low or whether they are a consequence of the market failures discussed in 2.5. 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 WTP for environmental quality and health (although it surely also reflects

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<sup>11</sup>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 et al. (2007) for examples of different methods). Many revealed preference studies of VSL or WTP rely on hedonic regressions to isolate the risk-price tradeoff, which relies on assumptions of well functioning markets that may not hold in developing country settings.

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 WTP, which capture the aesthetic, health and/or income gains from environmental quality.

### **3.2.2 Willingness to pay for self protection**

A larger number of studies measure WTP for self protection, which identifies  $WTP_s$  (equation 6) under a set of assumptions about household beliefs surrounding the health effects of self protection ( $h'(s)$ ). Berry, Fischer, and Guiteras (2011) estimate that the median WTP for a water filter in Ghana ranges between \$1.80 and \$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 WTP and self reported diarrheal reductions from the filter.

Willingness to pay for self protection may also vary within the household if the health burden of poor environmental quality is unevenly distributed across household members. Miller and Mobarak (2011) 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 Hussam (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 WTP may not accurately capture within-household heterogeneities. Both Berry et al. (2011) and Miller and Mobarak (2011) measure WTP for a (unfamiliar) product that affects experienced environmental quality, yet neither measures WTP for the ultimate change in environmental quality or 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 WTP for environmental quality in developing countries suggests extremely low valuations. While more evidence is needed, this finding raises questions about the underlying causes of low WTP. In addition, while low WTP 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 WTP might be low.

### **3.3.1 Explanation 1: High marginal utility of consumption**

Recall from equation 5 that WTP for environmental quality is determined not only by the endowment of environmental quality but also by the marginal utility of income. Increasing income or wealth may increase WTP for environmental goods as the marginal utility of consumption decreases. An ideal experiment would measure how WTP for environmental quality 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.

The three studies that are most relevant to the relationship between income and WTP 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, Berry, Fischer and Guiteras (2011) find no correlation between revealed WTP for water purification technology and assets. The relationship between income and WTP 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 WTP for environmental quality.

As suggested by the conceptual framework, higher incomes might be associated with both higher WTP for environmental quality but also larger impacts on the environment (if  $a'(c) > 0$ ). 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. (2011). 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. (2011) 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.<sup>12</sup> 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.

### 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.<sup>13</sup> Empirical evidence on the magnitude of  $c'(\Delta e)$  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 2013), 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 et al. 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

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<sup>12</sup>The transfer amount differed by gender and grade of school-aged children.

<sup>13</sup>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).

scale associated with the centralized provision of environmental quality. The result is high marginal costs of environmental quality improvements.

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 mortality. The paper also highlights the challenge of multiple environmental risks, and an inability of households or policy makers to accurately rank them.

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.<sup>14</sup> 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 with auditors systematically reporting plant emissions just below the standard, although true 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 et al. 2012). The extreme overestimate of the program's effectiveness was due to a combination of changes in the types of appliances purchase, usage patterns and the inclusion of many inframarginal households (Boomhower and Davis 2013; Davis et al. 2012).

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<sup>14</sup>Similar driving restrictions have been introduced and evaluated in other cities including Beijing, Santiago and São Paulo, with mixed success (Gallego et al. 2012; Lin et al. 2011; Viard and Fu 2011).

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. Lipscomb and Mobarak (2011) 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 un-penalized. While decentralization may lower the costs of improving environmental quality locally, it may simply shift these costs to other jurisdictions if pollutants are mobile.

Other investments in the economy, by policy-makers, 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 individuals treat public and private provision of environmental quality as substitutes. 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 WTP 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 are 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 2012a). 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 depend 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.

Other 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 City’s pollution control efforts (documented by Davis (2008) and Oliva (2010)). 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 (2013) 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 Dufflo 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.<sup>15</sup> In a different setting, Foster and Guitierrez (2009; 2011) investigate whether voluntary environmental programs can be effective, potentially addressing poor government enforcement through policy design. They rely on satellite measures of pollution

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<sup>15</sup>Other studies highlight the importance of targeting for decreasing the information rents in payments for environmental services studies. Arriagada et al. (2012) use difference and difference with pre-matching 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. Pfaff et al. 2008) and suggest that the difference is due to superior targeting in their region of study. See also a recent paper by Alix-Garcia et al. (2012).

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 due largely to the fact that participating firms underwent 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 in the first best, 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 policy maker'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 (2010) studies a pollution control policy in Mexico City's 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. 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. 2012). 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 (2009) 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 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). To the extent that competition increases the efficiency of the average firm, the pollution intensity of production may also be higher when rent seeking politicians set regulation.<sup>16</sup>

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 be 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 et al. 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.<sup>17</sup> Further research on the causal relationship between environmental quality,

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<sup>16</sup>Ryan (2012a) shows related evidence that reduced competition harms electricity provision in India. Dasgupta et al. (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.

<sup>17</sup>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)

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

If the assumptions of the first best are relaxed, then market failures may bias WTP ( $MB'$ ) away from its theoretical value ( $MB^*$ ). In particular, information, land, capital, and risk markets will affect WTP for environmental quality. 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 WTP and on investments in self protection, which implies that information market failures may move revealed preference measures away from the first best. 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. Another study in Bangladesh suggests that the effect of information is sensitive to how it is delivered (Benneer et al. 2012). 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 case for good reason as shown in the study by Field et al. (2011) described above. One reason for low measured WTP 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 et al. (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 title 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 pay-offs, which includes many environmental quality investments. On the other hand, 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 WTP for environmental quality, in particular, the size and direction of the gap between  $MB'$  and  $MB^*$ , and the costs of narrowing the gap. The substantial literature in development economics documenting plausibly exogenous sources of variation in market function should help facilitate future research.

Though studies of the behavioral effects of defaults have proliferated in other contexts, they have received relatively little attention for environmental decision making.<sup>18</sup> 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 tapped water experience a substantial improvement in quality of life and mental health, in spite of the lack of health impacts. 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 WTP. Further research on this and other areas of behavioral economics are a promising direction for future research, which can help identify the gap between  $MB'$  and  $MB^*$  in the social planner's welfare function.

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<sup>18</sup>A developed country exception is Lofgren et al. (2011), who study the effect of defaults on the purchase of carbon offsets.

### 3.4 Theory and Macroeconomics

The majority of the papers reviewed thus far are solidly within the realm of 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 sub-field.

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 2.5 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 et al. (1991) for seminal works in development economics and Baumol and Oates (1988); Cornes (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 2012b). 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 et al. (2004); Banerjee and Mullainathan (2010); Bryan et al. (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 Huetel and Fischer (2013) and Smith (2012) provide an overview of recent work and potential research directions at the intersection of traditional macroeconomics and environmental economics. Huetel and Fischer 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 (2012) 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 Huetel and Fischer (2013) in their review. The directed technological change literature is not the only macroeconomic sub-field 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 (2011); Hassler and Krusell (2012)) and the literature on trade and the environment (for example, Copeland and Taylor (2005); Shapiro (2012)) 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 at the intersection of environmental and development economics. 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. (2011); Wolfram et al. (2012)); China is currently the largest emitter of  $CO_2$  in the world and their emissions exceeded US emissions by 50 percent in 2012 (PBL 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 ( $a(c, s) \neq a^S(c, s)$ ), 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 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 cur-

rent 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. 2010; Deshpande and Greenstone 2010). 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 2-3 times more expensive than electricity generated from fossil fuels (Greenstone and Looney 2012).

In addition to these first best reasons (i.e., potentially low benefits and high costs) that slowing climate change may be difficult, this paper's other explanations for poor environmental quality in developing countries 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 cause revealed WTP for carbon reductions in developing countries to differ from first best WTP. 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. 2011; Deschênes et al. 2009; Deschênes and Greenstone 2011; Feng et al. 2010, 2012; Schlenker and

Lobell 2010; Graff-Zivin and Neidell 2012; 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, Deschenes, Donaldson and Greenstone (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 an significant role in moderating the effects of extreme weather on mortality (Barreca et al. 2012; Graff Zivin et al. 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 et al. 2012), though external migration incentives may be necessary even when the costs of not moving are very high (Bryan et al. 2012).

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 does 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 WTP 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 WTP 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 WTP?

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 WTP 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 people's decision heuristics and biases affect their willingness to use improved resources or technologies?
  - (d) How does access to credit for energy efficiency investments and investments in renewable energy sources affect individuals' and firms' decisions?
  - (e) Does worse environmental quality increase the variability of income? Do vulnerable groups use natural resources as a source of insurance? What is the corresponding WTP for this 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.

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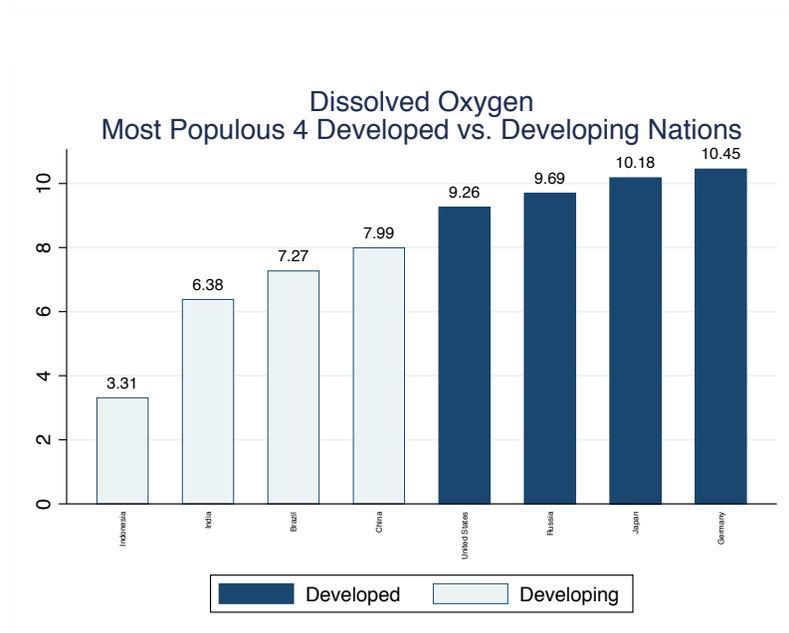
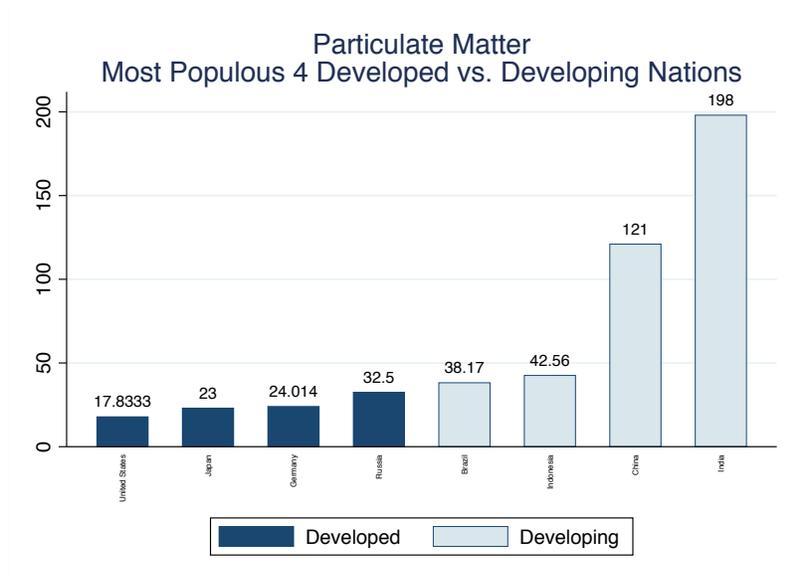
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Figure 1: Environmental quality in developed and developing countries

(a) Air pollution

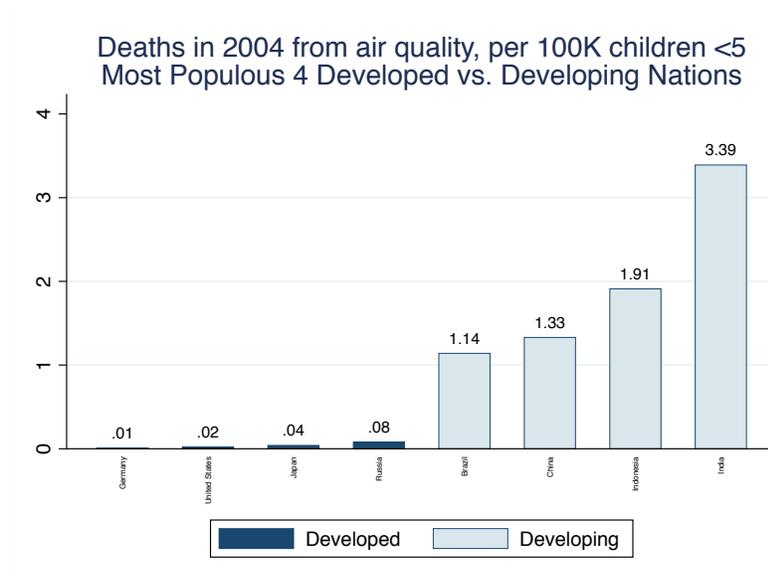


(b) Water pollution

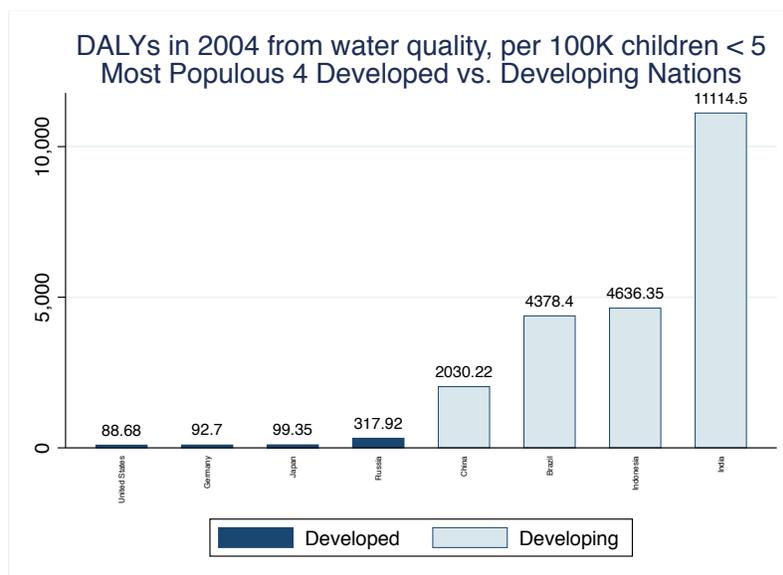
Notes: Panel A shows average particulate matter from urban centers, in  $\mu\text{g}/\text{m}^3$ , using data from the World Health Organization (2011). Panel B shows dissolved oxygen, in mls/litre, using data from the United Nations Environment Program (2001). The four most populous developed and developing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

Figure 2: Burden of diseases in developed and developing countries

(a) Disease burden from air pollution



(b) Disease burden from water pollution



Notes: Panel A shows the burden of disease in deaths among children under 5 per 100,000 from outdoor air pollution. Panel B shows the burden of disease in deaths among children under 5 per 100,000 from water, sanitation and hygiene. Data are from the World Health Organization (2004) for the 4 most populous developed and 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. (2011)
China	Water quality (index)	Stomach cancer deaths: 9.7 percent	Quasi experiment	Bangladesh
Bangladesh	Fecal coliform	Infant mortality: 27 percent	Quasi experiment	Field et al. (2012)
Kenya	E. Coli	Child diarrhea: 25 percent	RCT	Kremer et al. (2011)
Mexico	SO <sub>2</sub>	Labor supply: 0.61 hours/week	Quasi experiment	Hanna and Oliva (2012)
India	Agrichemicals	Multiple, child and infant health	Quasi experiment	Brainerd and Menon (2012)

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<sub>2</sub>). 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.

Table 2: Evidence for high marginal costs

Country	Finding	Methodology	Author (year)
Brazil	Decentralization increases water pollution	Fixed effects	Lipscomb and Mobarak (2012)
Mexico	Policy loopholes undermine effectiveness	Temporal discontinuity	Davis (2008)
Mexico	Voluntary certification lowers regulatory costs	Structural identification	Foster and Guitierrez (2009, 2011)
Mexico	Large inframarginal payments lower policy impacts	Fixed effects, RD	Davis et al. (2012), Davis and Boomhower (2013)
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 (2013)

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.

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. (2012)
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 (2012)

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

Table 4: Evidence on market failure-based distortions to WTP

Market failure	Country	Finding	Methodology	Author (year)
Property rights	Rwanda	Formal titling increased soil conservation	Spatial discontinuity	Ali et al. (2012)
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	Benbear et al. (2012)
Labor		No empirical evidence		
Credit		No empirical evidence		
Risk		No empirical evidence		

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