Symposium:
Environmental Quality and Economic Development

Show Me the Money: Do Payments Supply Environmental Services in Developing Countries?

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Why Do We Need Another PES Review?

Despite the billions of dollars invested in stemming the global loss of native ecosystems (James et al. 2001; Hardner and Rice 2002), ecosystem degradation continues (Achard et al. 2002; Balmford et al. 2002). The rapid degradation of ecosystems can partly be explained by the fact that many of the environmental services supplied by nature are externalities and that society has failed to create institutions that internalize the public values of intact ecosystems (Arrow et al. 2000; Pattanayak and Kramer 2001; Pattanayak and Wendland 2007). Dating at least as far back as Pigou (1920) and Coase (1960), economic theory suggests that some form of subsidy from the beneficiaries (buyers) of environmental services to the providers (sellers) of these services could result in an optimal supply. In recent years, a new paradigm for directly internalizing externalities has been labeled *payments for environmental services* (PES), reflecting the promise of contracting between service suppliers and beneficiaries (or governments acting on their behalf). While the theory of PES is relatively straightforward, the practice is much more difficult, particularly in developing countries, which face a plethora of institutional design and governance challenges.

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Interest in conservation payment approaches in developing countries has exploded in recent years. For example, Landell-Mills and Porras (2002) listed almost 300 examples of such mechanisms worldwide, and the number has grown since. Costa Rica's Pago por Servicios Ambientales (PSA) program, implemented throughout the country since 1997, is the best-known PES example. Established in 1996, PSA grew out of existing payments for reforestation and forest management, but focuses specifically on forest conservation. Financing comes from donors, earmarked taxes, and environmental service buyers. Since its inception, PSA has established contracts on approximately half a million hectares. The Sloping Lands Conservation Program (SLCP) in China is another large-scale example of PES, with contracts on 12 million hectares, focusing explicitly on reducing soil erosion through reforestation.[1]

There have been numerous recent reviews of PES (e.g., Bulte et al. 2008; Neef and Thomas 2009; Rebelo 2009). This article supplements these reviews, as well as the volumes that have been written on the theory and practice of direct conservation payments (Ferraro and Kiss 2002; Ferraro and Simpson 2002; Wunder 2007, Engel, Pagiola, and Wunder 2008; Wunder, Engel, and Pagiola 2008), by reviewing the empirical literature on the *additionality* of PES in developing countries.[2] That is, we attempt to answer the question, "Do payments deliver more environmental services, everything else being equal?" Our discussion will focus on developing countries for several reasons. First, developing countries contain much of the world's tropical forests, which have the potential to provide many critical ecosystem services through species conservation, climate regulation, watershed protection, carbon sequestration, and pure aesthetic benefits. Second, developing countries pose a special test for market-based solutions to conservation like PES because government and market institutions are weak. Finally, because developing countries are home to much of the world's poor, the allure of a potential win-win approach—reducing poverty and ecosystem degradation—makes PES irresistible to academics, policy makers, and program implementers alike.

Before turning to the details of PES, we briefly explain why this strategy of paying landowners to provide public goods may be of interest to a broader audience of economists working on related issues and concepts. First, development economists will be very familiar with the rapid rise and use of conditional cash transfers to improve human capital in poor settings—specifically educational and health outcomes (Fizbein et al. 2009). Second, environmental economists working on nonmarket valuation will be familiar with the idea of linking environmental functions to services (e.g., reduction of flooding-induced crop damages through watershed protection) by examining demand and preferences for services (Pattanayak and Butry 2005). Although much of the initial academic and practitioner efforts on PES were focused on the supply side, financing PES requires estimating how much the potential consumers are willing to pay and how to induce them to pay.[3] Finally, mechanism design

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[1] Additional details on these and other prominent PES programs in developing countries are presented in Appendix Tables 1, 2, and 3.

[2] This article is one of the four articles in the symposium on Environmental Quality and Economic Development featured in this issue. Vincent (2010) offers an introduction to the symposium and an overview of key issues; Blackman (2010) focuses on alternative pollution control policies in developing countries; and Somanathan (2010) examines how information affects environmental quality in developing countries.

[3] There is almost no overlap of the PES and nonmarket valuation literatures. Pattanayak and Kramer (2001) and Hope, Borgoyary, and Agarwal (2008) are some exceptions.

theorists, who focus on designing rules (e.g., contracts) to attain particular outcomes (e.g., targeted forest conservation), can help PES practitioners design programs and set up contracts that optimize the flow of environmental services from protected landscapes (Baliga and Maskin 2005).

We begin the next section with a brief review of the essential theory of PES. We then present observations from qualitative case study appraisals of PES, followed by a review of rigorous econometric evaluations of the additionality of PES in Costa Rica and other developing countries. As is often the case with economics, these empirical analyses are still playing "catch up" with theory and program implementation.[4] Because of space constraints and methodological differences, we do not discuss simulation studies that develop a conceptual model, parameterize it based on best guesses, and simulate outcomes.[5] Finally, we conclude by summarizing the promises and pitfalls of PES and discussing whether the lessons have any implications for the design or evaluation of climate change policies that use payments to landowners to reduce emissions from deforestation and degradation (REDD).

How Does PES Work in Theory?

The use of subsidies to compensate for positive externalities is an old idea (see Pigou 1920). As they have more recently been defined, however, PES are closer in spirit to Coase's (1960) critique of Pigou, in which Coase argues that socially suboptimal situations (e.g., too little provision of environmental services) can be resolved through voluntary market-like transactions, provided that transaction costs are low and property rights are clearly defined and enforced. For example, Wunder (2007) defines PES as a voluntary transaction between at least one buyer and at least one seller in which payments are conditional on maintaining an ecosystem use that provides well-defined environmental services. The payments thus provide a direct, tangible incentive to conserve the ecosystem and prevent encroachment by others.

The idea that direct conservation approaches such as PES could also be cost-effective has been articulated in a series of papers (Ferraro 2001; Ferraro and Kiss 2002; Ferraro and Simpson 2002; Simpson and Sedjo 1996). These papers assert that, in contrast to decades of "conservation by distraction" (e.g., integrated conservation and development projects) that have only indirect and often tenuous effects on conservation, direct payments such as PES schemes are likely to be (a) institutionally simpler; (b) more cost-effective in delivering benefits to buyers; (c) more effective in generating economic growth among suppliers by improving cash flow, diversifying income sources, and reducing income variance; and (d) provide new sources of finance for conservation.

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[4]For a lively debate on the balance between theory and empirics in the context of development policy, see the symposium in the October 2005 issue of *Economic and Political Weekly.*
[5]The typical approach in such studies is illustrated in Alix-Garcia, de Janvry, and Sadoulet (2008), who examine poverty and environmental goals of a PES program in Mexico. They find that while targeting can improve outcomes, politicians and environmental groups would favor different targeting strategies. For additional examples, see the special issue of *Environmental and Developmental Economics* (Bulte et al. 2008), and several papers by Ferraro (e.g., Ferraro and Simpson 2002). It is important to note, however, that these simulations are only as good as (a) the theory that they use, which we do not necessarily question; and (b) the parameters they employ, which are essentially unsubstantiated.

Because the poor often live in rural areas where intact ecosystems remain, PES could also help to reduce poverty. Pagiola, Arcenas, and Platais (2005) predict that the poor will be able to participate in PES schemes if they are: (a) eligible (e.g., ecologically in the "right place"); (b) disposed (e.g. payments exceed provision costs); and (c) able (e.g., have secure property rights). Wunder (2008) argues that, conditional on participation, poverty impacts depend on the rents paid to suppliers (difference between costs and payments) and on nonincome benefits such as improved local institutions. Zilberman et al. (2008) further suggest that the impacts of PES on the poor depend on farm size, the diversity and heterogeneity with respect to wealth, and any general equilibrium effects (e.g., increase in food or land prices because PES reduces farmland). They show, for example, that nonparticipants, such as the urban poor, landless, and small landowners, could lose under land-diversion PES programs. Wunder (2008) emphasizes that PES can also help poor nonparticipants, who may benefit indirectly from environmental services (e.g., poor urban water consumers). However, material welfare gains are likely to be small relative to national poverty-alleviation goals.

Information Asymmetries

Two important information asymmetries in contract design can weaken the impact of PES (Ferraro 2008): hidden information and hidden action. Hidden information (or adverse selection) arises when negotiating the contract. Landowners (i.e., suppliers) have better information than the buyer about the opportunity costs of supplying environmental services. As is well known, hidden information can lead to inefficient equilibria, for example, payments are too high. Hidden action (or moral hazard) may arise after a contract has been negotiated. That is, the conservation agent may find monitoring contract compliance expensive, and sanctioning noncompliance politically costly, and thus fail to enforce the contract (see next section). Under such conditions, the landowner has an incentive to breach contractual responsibilities.

Missing Markets

Further, payments may not prove as effective in conserving natural resources in regions with missing markets, i.e., where there are no market prices signaling the opportunity cost of supply to buyers or willingness to pay to sellers (Muller and Albers 2004). In such settings, subsistence choices depend on a household-specific shadow price, not a market price. For example, if the resource (fuelwood) market is incomplete, typical households would initially reduce the labor allocated to resource degradation (e.g., through fuelwood collection) in response to conservation payments (i.e., the direct effect). However, the income from the payment can also increase the demand for fuelwood (i.e., the shadow price effect). Whether the direct (decrease in fuelwood consumption) or shadow price effect (increase in fuelwood consumption) dominates determines whether forest degradation increases or decreases with conservation payments. This argument is a form of the theory of second-best— i.e., if one optimality condition cannot be satisfied (e.g., fuelwood market prices do not reflect opportunity costs), it is possible that the next-best solution involves allowing a suboptimal situation to persist in another market (e.g., not paying suppliers for the environmental services that flow from forest protection).

Non-Additional Protection

Sills et al. (2008) use these and other arguments to describe four scenarios that may result in the failure of PES to deliver *additional* amounts of protected ecosystems in practice. First, landowners may accept payments to "protect" ecosystems that they were not planning to convert to other uses (hidden information) because legal, economic, or biophysical constraints or landowners' environmental preferences had made conversion suboptimal. If landowners were already planning to protect the ecosystem, then payments are not needed. As discussed in more detail below, many case studies equate the impact of PES with the area under contract, which confuses additionality with compliance. These case studies conflate evaluation with monitoring by not explicitly considering the counterfactual (i.e., ecosystem services in the absence of PES).

Second, payments may indirectly impact land use, by either encouraging additional conservation (spillovers) or leading to deforestation (leakage) in areas not under contract. Spillovers related to PES contracts could arise from increased enforcement of existing laws, changes in social norms, or increased ecotourism opportunities as a result of greater regional ecosystem protection. Leakage could arise when landowners contract only parts of their land or when output and factor markets partially move environmental pressures from the protected area to an alternative one. Spillovers and leakage can affect the magnitudes of environmental and economic outcomes, and the effects will vary depending on the extent of spatial targeting of contracts (Wu et al. 2001). Additionally, if landowners are cash-constrained (e.g., due to credit market failure), payments could relax a key constraint for further land development and forest clearing.

Third, the prospect of PES could result in behaviors that alter baseline ecosystem conditions (hidden action) and therefore make it difficult to measure additional ecosystem protection. For example, if farm-level actions to encourage reforestation are assigned relative to baseline land use, farmers may deliberately increase deforestation to manipulate the baseline in order to earn higher payments. If undetected, such behavior would result in an overestimate of PES impacts. Clearly, good documentation of the baseline minimizes these risks. Alternatively, landowners may retain existing forest, reforest, or allow maturation of secondary forest not under contract to maintain the option of future payments (i.e., option value). This behavior would result in an underestimate of PES impacts.

Finally, even when PES result in additional forest conservation, the additional forested area may not yield additional environmental services. This is because ecosystem function is not the same as the provision of environmental services, even though the scientific literature and the general public often equate them (Pattanayak and Butry 2005; Sills et al. 2006). Ecosystem functions such as photosynthesis become valuable environmental service flows once we establish how a policy will change photosynthesis capacity and therefore plant and fruit production, which is consumed by people. Thus it is unclear, for example, whether the provision of water will increase (e.g., with native forest conservation) or decrease (e.g., with reforestation) under forest cover. Lack of scientific consensus has not, however, deterred the implementation of several programs to pay upstream landowners for downstream delivery of watershed services (see reviews by Porras, Grieg-Gran, and Neves (2008), Ferraro (2009), Southgate and Wunder (2009), and Huang et al. (2009)).

How Does PES Work in Practice?

In this section we review a rich literature that has tried to assess the promises, progress, and pitfalls of PES programs. We describe evidence from both qualitative case studies (summarized by Wunder, Engel, and Pagiola 2008) and rigorous econometric evaluations.

Observations from PES Case Studies

While these case studies do not estimate causal relationships between PES and environmental or socioeconomic outcomes, they still offer valuable insights, including where to focus future research. These studies engage in a form of economic archeology (Sills, Romero, and Sabido 2002), which involves digging through records kept by various governmental and nongovernmental organizations, reviewing the gray literature (including consultant reports commissioned by donors), conducting extensive interviews of key players, and engaging in rapid field appraisals for some ground truthing of satellite data or interview information. Such economic archeology complements rigorous econometric evaluations by elucidating important contextual details of the program, such as other drivers of ecosystem degradation and general trends. The approach is also consistent with iterative field research, in which the collection of data through surveys is combined with detailed observation and conversation to elicit institutional knowledge (Udry 2003). Arriagada et al. (2009) illustrate how qualitative observations from case studies and interviews in the Sarapiquí region facilitate a detailed understanding of Costa Rica's PES program (e.g., by identifying the main actors among government, private, and nonprofit sectors), and how landowners perceive their benefits and costs from the program. Their regression analysis of landowner decisions to participate in PES was informed by the fieldwork, and parallels recent calls for participatory econometrics (Rao 2002), in which the investigator returns to the field to clarify questions and resolve anomalies.

We do not attempt to catalog or represent the large PES case study literature. We direct interested readers to special issues of *World Development* (Pagiola, Arcenas, and Platais 2005), *Environmental and Development Economics* (Bulte et al. 2008), *Ecological Economics* (Engel, Pagiola, and Wunder 2008), *International Journal of the Commons* (Neef and Thomas 2009), and *Journal of Sustainable Forestry* (Rebelo 2009). The majority of the articles in these special issues are either case study summaries (e.g., Grieg-Gran, Porras, Wunder 2005), simulations based on highly stylized models (e.g., Alix-Garcia, de Janvry, and Sadoulet 2008), or simple descriptive regressions of participation in PES schemes (e.g., Zbinden and Lee 2005).

We do, however, summarize the findings of a recent special issue of *Ecological Economics* that includes detailed case studies of PES programs from around the world and offers a synthesis of the progress and limitations of current PES efforts (Volume 65, Issue 4, May 2008). The main criteria for selecting the specific case study programs were closeness to the archetype PES concept (Wunder 2007), broad geographical coverage, significance (in terms of geographic area and number of people covered), years in operation, and information availability. The characteristics of the developing country programs that were reviewed are summarized in Appendix Tables 1, 2, and 3. The details of user-financed schemes, in which funding comes from environmental services users, were found to differ substantially from government-coordinated PES programs, in which funding comes from government

revenues or third-party donors. The government-coordinated programs are described as less sophisticated in their design, either because of inexperience or the need to accommodate political pressures. Compared to government-coordinated programs, the user-financed programs are described as better targeted to landscapes, better able to deliver environmental services, more closely tailored to local conditions and needs, and having better monitoring, a greater willingness to enforce conditionality, and far fewer competing side objectives.

In an article that takes stock of all the programs reviewed in the special issue, Wunder, Engel, and Pagiola (2008) suggest that whether a PES program supplies environmental services depends on four related issues—enrollment, conditionality, additionality, and land use–service linkages (see Appendix Table 2):

1. *Enrollment*: Most of the PES programs had little difficulty in attracting potential environmental services providers (i.e., sellers). For example, applications exceeded the available funding by a factor of 3 in Mexico's PES program. However, there were important gaps in enrollment in areas of high-value water services, perhaps because opportunity costs in these areas exceeded the offered uniform payment.
2. *Conditionality (and compliance)*: In all cases, payments are nominally conditional on performance. Ensuring that PES recipients comply with their contracts requires appropriate monitoring, typically through site inspections and sometimes combined with remote-sensing satellite images. Monitoring quality typically varies over time, and depends on funding and politics. More critically, monitoring is not sufficient to ensure conditionality unless noncompliance is sanctioned. In most case studies, the primary sanction for noncompliance is the loss of future payments, either temporarily or permanently, rather than returning past payments (which can create time-inconsistent contracts). Conditionality was found to be generally lower in government-coordinated programs than in user-financed programs.
3. *Additionality*: A PES program will supply environmental services only if it induces land-use changes that would otherwise not have occurred (see next section). In principle, measuring additionality may be easier in programs that require explicit land-use changes such as reforestation because it would be unusual in a control site outside the program. Wunder, Engel, and Pagiola (2008) suggest that some user-financed programs delivered additional services. In Pimampiro (Ecuador), for example, previous deforestation trends were reversed in the program area, but continued apace in surrounding areas. Conversely, in Los Negros (Bolivia), most of the initial enrollment was in low-threat areas, indicating low additionality.
4. *From land use to ecosystem service*: Lastly, additional hectares of land-use change will only deliver services when these changes are of appropriate quality and location. For carbon sequestration projects, the link between land use (growing trees) and services (sequestering carbon) is generally well established and easily monitored. For watershed programs like Pimampiro or Los Negros, however, it is more difficult to demonstrate service provision because the underlying biophysical linkages are complex and remain largely unexplored (Bruijnzeel 2004).

Wunder, Engel, and Pagiola (2008) further suggest that PES will not be cost-effective in government-coordinated cases because of side objectives such as poverty alleviation, regional

development, and employment creation. For example, in Mexico, efforts to spread payments 'fairly' throughout the country meant that a substantial share of funding went to areas at little risk of deforestation or with limited or no threats to water supplies. In contrast, user-financed programs did not have side objectives (Appendix Table 1).

Whether or not poverty alleviation is an explicit side objective, the poverty impacts of PES are clearly relevant in developing nations. The case studies indicate that in most user-financed programs, service providers who are poor seem to be able to access the program and sell environmental services, while in government-coordinated programs, formal land title requirements obstruct participation. Most of the case studies claim that PES programs have likely delivered small net income gains to sellers. In addition, PES contracts were found to increase land tenure security in Costa Rica and Bolivia (Wunder, Engel, and Pagiola 2008). In summary, although conceptual models suggest PES can alleviate poverty under some conditions (Kerr 2002; Pagiola, Arcenas, and Platais 2005; Wunder 2008), the quantitative, empirical basis for attributing changes in poverty to PES remains limited.

Findings from Econometric Studies

Practitioners often confuse impact evaluation with efforts to monitor compliance and operations, which are more about studying inputs than outcomes or impacts. In order to identify the causal impacts of any program, the impact evaluator must determine the counterfactual: what would have happened in the absence of the program. However, the counterfactual is naturally unobservable because we can never know with certainty what changes would have occurred concerning program participants (the treatment group) if the program had not been implemented. Therefore, to estimate the counterfactual, impact evaluators must rely on control or comparison groups, as well as a number of statistical and econometric techniques. These tools help the analyst control for confounders, which are factors or events that also affect the measured outcomes and are correlated with the intervention.[6]

Thus, to separate an intervention's impact from confounders, impact evaluations must use either experimental or quasi-experimental designs that seek to credibly eliminate rival explanations for observed outcomes.[7] However, such empirical designs are rare in the PES literature. In fact, few studies manage to meet even one of the four rules-of-thumb recommended for evaluating conservation interventions (Ferraro and Pattanayak 2006): (1) identify ecological and socioeconomic factors that co-vary with the program and which might influence the outcome measure; (2) guess-estimate the direction of potential bias in interpreting intervention effectiveness; (3) construct simple control groups (those that do not

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[6]Confounding can be caused by contemporaneous changes in conditions that affect outcomes, or by participants differing from nonparticipants in economic or psychosocial factors that affect the outcomes. The latter selection bias can result from participant self-selection into the program or from administrative targeting to certain populations and or locations. Case studies typically do not address concerns about confounding.

[7]The quasi-experimental designs that use econometrics to compare intervention to "controls" include: (a) matching—finding a control group that "matches" important observable characteristics of the program group; (b) instrumental variables—using variables that are uncorrelated with the outcome but correlated with program participation to identify a control group; (c) difference-in-difference—using repeated measures of the same individuals (units) to account for time-invariant differences between control and program groups; and (d) Heckman two-stage models—using covariates to predict who participates and using the predicted probabilities to correct bias when comparing controls to program groups (Ravallion 2007).

receive the program) to represent the counterfactual; and (4) collect baseline and follow-up data on outcomes and key inputs.

Table 1 presents a summary of the few such rigorous empirical evaluations that meet these rules of thumb. These empirical studies, which examine PES programs in Colombia, Mexico, China, and Costa Rica,[8] find that there are small effects of PES. Given how long these programs have been in operation, perhaps it is simply too early to tell. We return to this issue in the final section. Even though much of the work summarized in Table 1 has undergone peer review and public presentations, it is still largely unpublished. The lack of a more substantial literature on PES evaluations reflects the fact that the practice of impact evaluation is relatively new to conservation policy (Greenstone and Gayer 2009).

Colombia

We start with an examination of an early PES project in Colombia—the Regional Integrated Silvopastoral Ecosystem Management Project (RISEMP)—which focused on program participation by poor households (Rios and Pagiola forthcoming). The authors attempted to include a control group of landowners, but unfortunately found ex post that the characteristics of control group members differed from PES contract holders in many important respects (such as income, farm size, or herd size). While the regression analysis suggests that RISEMP had a modest positive impact on a stylized index of environmental services and no impact on land-use change, the results are limited by a weak design and small sample.

Mexico

Alix-Garcia, Shapiro, and Sims (2010) recently began an evaluation of Mexico's Payments for Hydrological Environmental Services—using a combination of matching and regression methods. Thus far, they find that program participants deforest their properties 10 percent less than matched controls selected from denied program applicants. Their estimate of a positive impact is net of substitution within a participant's landholdings—e.g., it includes leakage of deforestation into communal lands. They also find that the impacts differ by property types and regions.

China

Next we consider the only known rigorous impact evaluation of China's SLCP. Using household panel surveys, Uchida, Rozelle, and Xu (2009) find that the SLCP allowed households to shift their labor allocation from on-farm to off-farm labor by relaxing households' liquidity constraints. However, we do not know of any evaluation that examines the land-cover and land-use impacts of the SLCP.

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[8]An evaluation of PES programs is currently underway in Nicaragua, Costa Rica, and Colombia (S. Pagiola, personal communication, June 2009). However, the selection of control groups proved problematic, thus limiting what can be learned (Vaessen and van Hecken 2009).

Table 1: Rigorous impact evaluations of PES programs and projects

Study	Location	Design	Sample	Methods[10]	Outcomes & Impacts[9]		
					Land-use change	Ecosystem services	Welfare & socio-eco
Rios & Pagiola (forthcoming)	Quinindo, Colombia	Observational	72 PES contracts, 29 controls	Tobit/OLS	n.s.	3.6 ecosystem services pts.	∼
Alix-Garcia, Shapiro, and Sims (2010)	Mexico	Quasi-experimental	352 PSAH contracts, 462 controls	Matching & regression	−10% deforestation		
Uchida, Rozelle, and Xu (2009)	China	Quasi-experimental	230 participants, 40 controls[11]	PSM & DID	∼	∼	15-20% off-farm labor
Sierra & Russman (2006)	Osa, Costa Rica	Observational[12]	30 PES contracts, 30 controls	OLS	0.4 ha fallow −0.25 ha forests	∼	∼
Sills et al. (2008)	Sarapiqui, Costa Rica	Quasi-experimental	44 PSA contracts, 119 controls	PSM & DID	3–10 ha natural forests[13]	∼	∼
Arriagada et al. (2008)	Costa Rica	Quasi-experimental	1019 PSA tracts, 519 controls	PSM & DID	25–35 ha reforested[14]	∼	∼
Pfaff, Robalino, and Sánchez-Azofeifa (2008)	Costa Rica	Quasi-experimental	40 PSA pixels, 40–240 controls[15]	PSM	<−1% deforestation	∼	∼
Robalino et al. (2008)	Costa Rica	Quasi-experimental	925 PSA pixels, 925–4625 controls	PSM	−0.4% deforestation	∼	∼

[9]n.s. implies impact was "not statistically significant" and ∼ implies impact was not studied.

[10]Acronyms for statistical methods are as follows: OLS, ordinary least squares; PSM, propensity score matching; DID, difference-in-difference estimation.

[11]Uchida, Rozelle, and Xu start with a sample of 270 households, none of which was participating in SLCP in 1999. In 2002 (second measurement), there were 201 participants, and by 2004, the participants totaled 230, with the remaining 40 households comprising the control group.

[12]The study included control farmers based on farm size (30 ha <selected farms <350 ha) but did not report how similar the controls were.

[13]The analysis starts with a sample of 200 (50 PSA contract holders and 150 controls), but ends with a sample of 163 landowners because of sample attrition because of PSM.

[14]Arriagada et al. start by comparing 1,065 census tracts with PSA contracts to 7,138 census tracts without PSA contracts. The matching process reduces the overall sample to 1,538.

[15]The sample of potential controls is 1,710. They use single, dual, and multiple (as many as six) in their PSM estimation.

Costa Rica

Finally, we turn to Costa Rica—the country with the most intensive and rigorous evaluations. Evaluations of the PSA program have focused largely on land-use outcomes (e.g., hectares of forests conserved). As the only long-term, large-scale payment initiative for tropical forests, Costa Rica's PSA program provides a unique opportunity to evaluate direct payments as a conservation policy tool. There is sufficient experience to test the underlying hypothesis that PES reduces deforestation using parcel and regional data. However, we must be cautious in extrapolating from the case of Costa Rica, which is unique in many ways. In particular, by the time the PSA program was launched in Costa Rica, the country was well on its way to reversing deforestation, partly through aggressive conservation policies in the 1980s, and partly because other deforestation threats had been reduced (e.g., the crash in global beef prices).

Parcel-Level Analyses

We start with two analyses of landowner parcels in the Osa Peninsula (Sierra and Russman 2006) and Sarapiqui region (Sills et al. 2008). Sierra and Russman define the counterfactual as the outcome of nearby livestock ranchers and control for parcel size and contract length. Sills et al. use more complex sampling and matching methods to identify similar landowners across many (>10) observable dimensions. Both studies come to the same qualitative conclusion: the PSA had small impacts on land use in Costa Rica. Sills et al. summarize several plausible reasons:

1. Several studies, including Arriagada et al. (2009), report that the lack of alternative uses for contracted land appears to have the greatest influence on decisions to participate in PSA. Thus, many landowners had never intended to convert the mature forest they placed under PSA contract, for economic or legal (e.g., deforestation was banned in Costa Rica) reasons.

2. The results could also reflect leakages to other areas of the farm, which landowners convert or prevent from regenerating to compensate for the area now under PSA contract. The cash payments from FONAFIFO, the autonomous government agency, may even have facilitated this by relaxing credit constraints.

3. PSA contracts could have positive spillovers to neighboring control plots that are not captured by Sierra and Russman (2006). For example, landowners may learn about and plan to apply for PSA due to their neighbors' experience with PSA. Arriagada et al. (2009) find that 40 percent of survey respondents discussed PSA with their neighbors. Neighbors of properties with PSA contracts may also be subject to greater monitoring for illegal deforestation. Arriagada et al. (2009) also found that the number of times a farm has been visited by an environmental agent in the past 10 years increases with proximity of the agency office to PSA properties. To control for these factors that may bias simple participant-neighbor comparisons, Sills et al. explicitly avoid neighbors within a 3-km buffer and control for proximity to an environmental office. Yet, they still find a small impact.

4. While the estimated impact of PSA on forest cover is small, it is possible that the program has a larger impact on forest quality by encouraging better management and protection of forests. For example, participants in Sarapiquí report that they actively protect the forest by maintaining trails, guarding contract areas, and fencing the forest (Arriagada et al. 2009).

5. Sierra and Russman (2006) suggest that PES may accelerate the exit from agriculture and thus forest regrowth may have gone undetected in their study.

Regional-Level Analyses

Costa Rica's PSA program has also been analyzed at a regional level (Arriagada et al. 2008; Pfaff, Robalino, and Sánchez-Azofeifa 2008; Robalino et al. 2008). While the unit of analysis is no longer the individual landowner, such an approach at least partially captures any spillovers and leakages. Arriagada et al. (2008) combined census data (INEC 2007) with land cover maps derived from satellite images (ITCR 2005) at the census tract level and applied propensity score matching to evaluate PSA impacts.[16] In matched samples of tracts, they find no difference in rates of forest loss between 1997 and 2005. That is, the gross deforestation rate is the same in both PSA and non-PSA tracts. However, PSA contracting in a tract did result in 24–34 hectares more net forest gain because reforestation rates were higher than deforestation rates. This impact on net forest cover represents less than 2 percent of the average tract size.[17]

Pfaff, Robalino, and Sánchez-Azofeifa (2008) used a similar approach, but different spatial units (i.e., pixels), and found that PSA has a small or no impact (less than 1 percent of the enrolled land) on deforestation. Using the same approach, Robalino et al. (2008) examined the recent contracts (2000–2005) and found that less than 5 in 1000 (∼0.4 percent) parcels enrolled in the program would have been deforested annually had there been no payments. These results confirm the findings reported in Sánchez-Azofeifa et al. (2007).

Promises and Pitfalls of PES and REDD

In this final section, we summarize the promises and pitfalls of PES as a strategy for conserving ecosystems and generating environmental services. We then reflect on the connections between PES and REDD (reduced emissions from deforestation and degradation), which represents the new hope for rigorous evaluations of PES. We conclude with some final words

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[16]Matching is a technique to reduce observable sources of bias in an observational (nonexperimental) study by ensuring the covariate distributions of treated and control units are similar (called covariate balancing). Matching can be viewed as a way to make the treated and control covariate distributions look similar by reweighting the sample observations.

[17]To examine if the impact of PES varies with its intensity (e.g., the size of payment or percentage of a parcel or tract under contract), Arriagada et al. (2008) also analyzed PSA impact using a continuous definition of treatment. By estimating a dose–response function, PSA protection thresholds are calculated that indicate the maximum level of protection per tract in order to observe expected program impacts (e.g., positive impact on forest gain and net deforestation and negative impact on forest loss). The results suggest that intensity matters: PSA impact on forest gain and net deforestation follow the hypothesized pattern up to a certain percentage of tract area under PSA protection. After reaching that threshold, however, the effect no longer increases.

on the findings from our review of the PES literature and our concerns about the current state of PES.

Has the Theory About PES Been Right?

The case studies reviewed above suggest that PES programs promise supply-side and demand-side innovations (Wunder, Engel, and Pagiola 2008). On the supply side, PES programs insist on conservation as a *quid pro quo*: those who voluntarily provide valuable services should be compensated. Just as importantly, they will be compensated only if they do in fact provide services (conditionality). However, PES programs offer few gains if the compensated services are not additional. On the demand side, PES programs offer the possibility of increasing conservation funding, in some cases reducing the responsibilities of governments that often lack well-trained bureaucrats and sufficient budgets. As the literature on decentralized forest management contends (e.g., Somanathan, Prabhakar, and Mehta 2009), governments may not be well placed to identify and provide environmental services. In principle, direct payments by users bypass many of these constraints by generating "new" funds from informed users, who should have strong incentives to make sure that this funding is spent efficiently.

Nevertheless, in addition to the concerns raised in the discussion above on PES theory, critical questions concerning PES remain unanswered. The first set of concerns is associated with any process that involves creating market-type transactions against a backdrop of weak institutions and missing markets (Muller and Albers 2004). Many of the world's problems rely on the complementary roles of government regulation, community norms, and market signals to narrow the wedge between private and "optimal" social behaviors. For example, Rios and Pagiola (forthcoming) draw on the technology adoption literature to suggest that tenure, credit, technical assistance, and full information are important for effective (and fair) PES operations.

The second set of concerns relates to simplistic models of constrained optimization by suppliers. Payments can clearly induce landowners to protect ecosystems, but in certain cases (e.g., small payments), payments may reduce landowners' private conservation incentives, and thus weaken their overall instincts to conserve (Cardenas, Stranlund, and Willis 2000). One might worry that crowding out pro-social preferences (e.g., conservation ethic) with private incentives (e.g., payments) could be irreversible. More generally, experimental evidence from behavioral economics suggests that responses to financial incentives (e.g., payments) may vary in ways that are different from those predicted by simple models of rational choice, for example, because of (a) loss aversion; (b) fairness and altruism concerns; and (c) time-varying preferences (Anderson 2006).

The Dire Straits of Evidence-Based Practice in Ecosystem Conservation

A previous essay made a plea for testing hypotheses about the effectiveness of conservation investments using the same scientific rigor and state-of-the-art methods that are used to test ecological hypotheses (Ferraro and Pattanayak 2006). We would like to reiterate the call for using such evidence-based methods for evaluating PES. Our understanding of whether and how PES (and other conservation tools) protect ecosystems rests primarily on simple case studies, narratives, and anecdotes from field initiatives that were not designed to answer

the fundamental additionality question, "Does PES work better than no PES intervention in delivering environmental services?" While we recognize the multidimensional nature of monitoring and evaluation, and the positive contributions of such "economic archeology," we also see an urgent need for quantitative causal analyses of PES effectiveness. Such analyses would deliver the hard numbers needed to give policy makers greater confidence in scaling up PES.

Impact analyses can be conducted through more creative collection of primary and secondary data sets, and the use of well-understood quasi-experimental econometric methods, such as those discussed in the previous section. These approaches have been applied in other conservation policy contexts, such as impacts of protected areas on forest cover in Costa Rica (Andam et al. 2008), Integrated Conservation and Development Programs (ICDP) on economic welfare in Brazil (Weber et al. 2009), and decentralized management on forest cover in Nepal (Edmonds 2002) and India (Somanathan, Prabhakar, and Mehta 2009), and forest incomes in Malawi (Jumbe and Angelsen 2006). An equally fruitful path would be for researchers to participate directly in PES program development by applying lessons from mechanism design theory and generating exogenous variation in payment assignment or other aspects of the program intervention. The case studies indicate that many PES programs have eligibility requirements that could be exploited in quasi-experimental designs, as well as sequential phase-ins, excess demand, or limited promotional budgets that in some cases could be randomized to make identification of impacts easier.

REDD Storm Rising

We next discuss PES in the context of perhaps the most serious ecosystem-related challenge facing society—climate change. REDD represents an array of international programs and projects to reward landowners, communities, and countries in tropical regions for reducing greenhouse gas (GHG) emissions from deforestation. The design of REDD programs already reflects the influence of past and current experience with PES in the sense that conditionality is a key design characteristic (Angelsen et al. 2009). Thus, it is very likely that many REDD projects will ultimately be PES-like projects. In most REDD proposals, payments are only to be made if there are improvements relative to a historical or predicted deforestation baseline. This conditionality feature is a sharp, but promising, departure from previous international efforts to slow tropical deforestation. Time will tell how seriously this *quid pro quo* will be taken by donors and recipients. As with government-coordinated PES programs, the political costs for donors of withholding money are often very high and therefore they will likely ignore noncompliance. It may be even harder to achieve the key goal of additionality rather than just simple compliance.

Arguably, REDD's second promising feature is its scale. Small-scale PES may generate leakage because of partial displacement of emission-generating land uses locally, although the extent to which this leakage takes place is debated (Chomitz 2006). More critically, perhaps, PES may not address key drivers of deforestation—such as commodity prices, road construction into forests, and other extrasectoral trends and policies. REDD, however, is frequently conceptualized as targeting national-level deforestation rates, which forces governments to be accountable for leakage and extrasectoral factors that promote deforestation. Thus, to a large degree, REDD can be seen as an international PES: governments will be paid if and

only if they reduce forest-based emissions beyond what would otherwise have been the case. Governments also have the option of using PES at a subnational level for on-the-ground implementation (e.g., starting with pilot projects and eventually scaling up). The use of PES at the subnational level has the advantage of permitting the set up of spatially specific deforestation targets, which can form part of the country's obligation to reduce national deforestation.

Because REDD focuses on the carbon sequestration services of forests, it is also important to consider the issue of *permanence* of service delivery. In general, we do not know if payments will deliver environmental services in the long run, as, unfortunately, most PES programs have been in operation for too little time to offer empirical evidence. But how might long-term service delivery work in principle? If the externality underlying PES is permanent (e.g., for forest conservation), there is no reason to believe that a service will be provided after payments end (Wunder, Engel, and Pagiola 2008). On the contrary, the persistence of PES-promoted land uses after the end of payments could indicate that overall the payments did not result in any additionality. While a PES program is operating, service provision will depend primarily on compliance and continued financing of the program. This depends on the users being satisfied with the service they receive and continuing to allocate budgets to sustain the program.

Our optimism about the potential for REDD to improve PES evaluations stems from three features of REDD. First, it has the clear goal of additionality. Second, large amounts of international resources are being poured into its design and the implementation of pilot initiatives. We are confident that some fraction of those resources will be devoted to monitoring and evaluation. Third, given the advances in science and remote sensing, carbon storage is becoming easier to measure and monitor, especially compared to biodiversity and watershed services.

Final Thoughts

Although it is not unusual for empirical research to lag well behind theory, policy design, and implementation, the current state of PES is cause for concern. Not only do we see nominal monitoring and sanctions to ensure conditionality (see Appendix Table 2), but we also see very little evaluation of additionality (see the short list in Table 1). While the case studies illustrate many promising aspects of PES, we do not yet fully understand either the conditions under which PES has positive environmental and socioeconomic impacts or its cost-effectiveness. While we also lack such understanding of alternative conservation policies, including ICDPs, protected areas, and environmental education, the dearth of evidence in the case of PES stems partly from the short lifespan of the concept itself. Thus it is not surprising that Costa Rica, which has one of the longest-running PES programs in the world, is the only program with multiple rigorous evaluations. However, the continued poor understanding of program implementation and the continued lack of data collection to facilitate evaluations suggest there will be little growth in the evidence base in the near future. Alternatively, if more PES programs were designed at the outset with the intention of evaluating their effectiveness, it would make a vital contribution toward filling the large gap in our knowledge about effective conservation investments, including those related to realizing REDD's potential.

Appendix Table 1: Summary of PES case studies (adapted from Wunder, Engel, and Pagiola 2008)

Case, country	Environmental services		Who buys?	Who else benefits?	Who sells?	Who initiated?	Start year	Spatial scale and current size (hectares)	Side Objectives
	Targeted	**Paid for**							
				User financed					
Los Negros, Bolivia	Watershed and biodiversity protection	Forest and páramo conservation	Pampagrande Municipality, U.S. Fish and Wildlife Service	Local water users, mostly irrigators	Santa Rosa farmers (46 landowners)	Fundación Natura (NGO)	2003	Upper Los Negros watershed (2,774)	None
Pimampiro, Ecuador	Watershed protection	Forest & páramo –conservation/ restoration	Metered urban water users (20% fee)	Unmetered water users, irrigators	N. América Coop. (81% of members)	CEDERENA (NGO)	2000	Palahurco watershed, left side (496)	None
PROFAFOR, Ecuador	Carbon sequestration	Re- and af-forestation	FACE (Electricity consortium)	Climate-change mitigation beneficiaries	Communal and individual landholders	PROFAFOR (company set up by buyer)	1993	Highlands and coastal regions (22,300)	None
				Government-coordinated					
Sloping Land Conversion Program (SLCP), China	Watershed protection	Cropland retirement, conversion to grasslands, re- and afforestation	Central government	Downstream water users, timber consumers	Rural households	Central government	Pilot 1999–2001, full scale 2002-	7.2 million ha retired and 4.92 million reforested (2005)	Poverty reduction, grain subsidies, timber production
Payments for Environmental Services (PSA), Costa Rica	Water, biodiversity, carbon, scenic beauty	Forest conservation, timber plantations, agroforestry	FONAFIFO (autonomous state agency)	Tourism industry, water users	Private landholders, indigenous communities	Government, in Forest Law	1997	National, target areas, 270,000 (end 2005)	Poverty reduction
Payments for Hydrological Environmental Services (PSAH), Mexico	Watershed and aquifer protection	Conservation of preexisting forest area	CONAFOR (state forest agency)	All water users in watershed and those using aquifers	Communal and individual landowners	Ministry of Environment, Forest & Water Commissions	2003	National, priority areas, 600,000 (2005)	Implicit biodiversity and poverty criteria

Appendix Table 2: Design features of PES case study programs (adapted from Wunder, Engel, and Pagiola 2008)

Case	Seller selection	Conditionality	Monitoring	Sanctions	Baselines & scenarios	Additionality	Land-use–service link
Los Negros	Village focus: high threat + strategic service site	High in principle—but de facto still untested	Yearly site inspection	Temporary PES exclusion (not applied so far)	Implicit—declining natural vegetation	Probably low, as low-threat areas are enrolled	Assumed, not proven
Pimampiro	Village focus: high threat + strategic service site	High, lately some decline	Quarterly site inspection—now deteriorating	Temporary or permanent PES exclusion (applied)	Implicit future scenario—likely decline in natural vegetation	High, for land use: clear trend change towards conservation	Assumed, not proven—likely in part
PROFAFOR	Biophysical conditions, price, minimum size, clusters	High for individual owners, lower for communities	Yearly site inspection + aggregate model	PES payback + land mortgage (applied to individuals only)	Explicit—static land use	High (vis-à-vis baseline)	Explicit
SLCP	Based on land slope, plot size, retired land contiguity	High for area retired, lower for successful forest plantation	Frequent by village officials, less by township/ county, random by upper-level government	Withholding of subsidies—but weak enforcement	Implicit	High for land retirement; lower for reforestation	Assumed so far—ongoing research to quantify
PSA	Priority areas (currently based on biodiversity and poverty criteria, but water criteria being added)	High	Compliance monitored by private forest engineers, with sample audited	Loss of future payments	Explicit static forest-cover baseline	Unclear—studies give widely divergent results	Explicit, good research on impact of aliens on water runoff
PSAH	2003 almost random, 2004 basic grading + regional balance, 2005 grading in place	High compliance with respect to. forest-cover conservation (water service not monitored).	Forest cover: yearly satellite image analysis; random (few) site visits	Intentional: current + future payments cancelled (3 cases in 2 yr) Unintentional (fire etc): affected area is not paid for	Explicit static forest cover baseline; threat area modeling	Unknown—but evidence that some low-threat areas are offered	Extensive research, but not explicitly modeled

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Appendix Table 3: Payments to providers & transaction costs of PES case study programs (adapted from Wunder, Engel, and Pagiola 2008)

Case	Opportunity costs	Mode of payment	Payment amount, cash equivalent (U.S.$/ha/yr)	Timing of payment	Differentiation (spatial, other)	Contract duration	Transaction Costs (U.S.$) Start-up	Transaction Costs (U.S.$) Recurrent
Los Negros	Not studied	In-kind + Technical Assistance	1.5–3.0	Annual, ex-ante	Higher for cloud forest	Variable length (1+ yr)	46,000 (17/ha)	3,000/ yr (1/ha)
Pimampiro	Not studied	Cash	6–12	Monthly, post-monitoring	Higher for primary vegetation	Initially 5 yrs , now unlimited,	37,800 (76/ha)	3,600/yr (7/ha/yr)
PROFAFOR	Only labor costs known	Cash + in- kind technical assistance	100–200 (up front)	Years 1–3 plus tree harvests	Yes, site-level negotiation	15, 20, or 99 yrs	4.1 million (184/ha)	76,600/yr (3/ha/yr)
SLCP	Only roughly known	Cash + grain (phased out), + free seedlings + technical assistance	Nominal cash: 36; de facto lower, highly variable	Annual, normally	Higher in Yangtze River than Yellow River Basin	Max. 8 yr for timber, 5 yr orchards, 2 yr grassland	NA	NA
PSA	Not studied, but implicitly based on extensive grazing	Cash	45–163	Annual, after monitoring compliance	None	5-yr forest conservation (renewable), 15-yr timber plantation	NA	7% of payments (limited by law); some costs pushed onto providers
PSAH	Estimates suggest payments > opportunity costs for 30% of targeted areas	Cash	27–36	Annual, ex post	Higher for cloud forests	5 yr (conditional renewal)	NA	4% of payments (limited by law)

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