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The Effectiveness of Payments for Environmental Services

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Summary. — We adopt a theory-based approach to synthesize research on the effectiveness of payments for environmental services in achieving environmental objectives and socio-economic co-benefits in varying contexts. Our theory of change builds on established conceptual models of impact pathways and highlights the role of (1) contextual dimensions (e.g., political, institutional, and socio-economic conditions, spatial heterogeneity in environmental service values and provision costs, and interactions with pre-existing policies), and (2) scheme design (e.g., payment type and level, contract length, targeting, and differentiation of payments) in determining environmental and socio-economic outcomes. To shed light on the overall effectiveness of payment schemes, and its determinants, we review counterfactual-based empirical evaluations, comparative analyses of case-studies, and meta-analyses. Our review suggests that program effectiveness often lags behind the expectations of early theorists. However, we also find that theory has advanced sufficiently to identify common reasons for why payment schemes fail or succeed. Moreover, payment schemes are often rolled out along with other policy instruments in so-called policy mixes. Advances in theory and evaluation research are needed to improve our understanding of how such policy mixes interact with the targeted social-ecological systems.

Key words — payments for ecosystem services, environmental effectiveness, trade-offs, policy design, impact evaluation

1. INTRODUCTION

Over the past two decades, a rich academic debate has emerged around the effectiveness of payments for environmental—or ecosystem—services (PES) (Muradian *et al.*, 2013; Pattanayak, Wunder, & Ferraro, 2010). Dozens of PES initiatives have been implemented in communities, regions, or countries around the world (Ezzine-de-Blas, Wunder, Ruiz-Pérez, & del Pilar Moreno-Sanchez, 2016). These programs provide land users with an incentive to protect or enhance the provision of ecological or environmental services (Daily, 1997). Well-studied examples of PES programs include the Costa Rican and Mexican national programs for forest protection (Alix-Garcia, Shapiro, & Sims, 2012; Pagiola, 2008), agri-environmental policies in the USA and the EU (Baylis, Peplow, Rausser, & Simon, 2008), and the Chinese Sloping Land Conversion Program (Bennett, 2008).

The literature on PES has grown rapidly. According to Google Scholar, [1] an average of 1715 articles per year was published on the topic during 2010–15. The early literature tentatively defined the concept of PES and documented the first field experiences with this type of program (Ferraro & Kiss, 2002; Landell Mills & Porras, 2002; Muradian, Corbera, Pascual, Kosoy, & May, 2010; Wunder, 2005). Summarizing the debate on the definition of PES, Wunder (2015) concluded that "…PES can be defined as voluntary transactions between services users and service providers that are conditional on agreed rules of natural resource management for generating offsite services" (Wunder, 2015: p. 241).

The literature on PES features descriptive case studies, theoretical work on incentive design and behavioral responses, systematic reviews, and a small but increasing amount of counterfactual-based impact evaluations. In the early years of PES evaluation studies (2003–11), PES programs were still being piloted, designed and tested (Asquith, Vargas, & Wunder, 2008; Engel, Pagiola, & Wunder, 2008; Kosoy, Martinez-Tuna, Muradian, & Martinez-Alier, 2007; Wunder, 2005). The PES concept was pioneered in Costa Rica, where a national payment scheme was set up in 1997 to maintain and enhance environmental service provision in the forestry sector (Pagiola, 2008). In industrialized countries, large-scale incentive-based programs had also previously been designed to protect agricultural soils and retire environmentally sensitive lands. One of the earliest agricultural payment schemes, the Conservation Reserve Program in the United States (initiated in 1985), was found to have reduced soil erosion on participating farms (Goodwin & Smith, 2003). After the EU agricultural reforms in 2001, multiple programs under the Common Agricultural Policy paid farmers to undertake conservation measures on farms, such as reducing input use inten-

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sity and preserving habitat (Baylis *et al.*, 2008). China was also an early adopter of PES, introducing the sloping-land conversion program in 2002, which paid participants to restore large tracts of marginal agricultural land with trees or grasslands (Xu, Bennett, Tao, & Xu, 2004). Much research during this early period focused mostly on developing monitoring indicators and collecting data on outcomes to inform program design (Honey-Rosés, López-García, Rendón-Salinas, Peralta-Higuera, & Galindo-Leal, 2009).

As PES gained popularity among researchers and practitioners alike, an increasing number of conceptual and empirical studies identified potential drawbacks. Payment schemes were alleged to potentially reinforce tradeoffs between environmental and social outcomes or to induce adverse behavioral effects (Corbera, Kosoy, & Martinez Tuna, 2007; Muradian *et al.*, 2013; Pascual, Muradian, Rodríguez, & Duraiappah, 2010). Some case studies also highlighted that PES are frequently part of a policy mix, where policy instruments interact, deliberately or not, in producing both desired and undesired outcomes (Howlett, 2004, 2009; Barton, Blumentrath, & Rusch, 2013). Clearly, when payment schemes are embedded in complex social-ecological systems, outcomes can be the result of multiple interacting factors. Such complexity makes it difficult to attribute impact from simple before-after and/or with-without comparisons. To understand the true effect of PES programs, scholars are pushing the PES literature to adopt counterfactual-based evaluation approaches and construct a systematic evidence base, such as in medical or development research (Baylis *et al.*, 2016; Ferraro, 2011; Pattanayak *et al.*, 2010).

Given the sustained interest in PES, much has been written about the potential benefits and pitfalls of payment-based approaches in environmental governance (Muradian *et al.*, 2013; Wunder, 2013). Yet, it has not always been clear whether arguments rest on theoretical considerations, case-study-based anecdotal evidence, comparative analysis, or counterfactual impact evaluations (Corbera, 2015). Here we aim to shed light on these issues by summarizing what we know so far about the conditions under which payments can achieve environmental objectives and socio-economic co-benefits.

Section 2 begins with a fresh look at how PES is thought to induce positive environmental and socio-economic outcomes (i.e., a theory of change), highlighting which PES design features and implementation contexts are key to such outcomes (White, 2009). While it is too early to draw externally valid conclusions from the still small number of counterfactual-based PES evaluation studies, Section 3 synthesizes currently available findings. A systematic global PES review is beyond our scope, but we seek to extract the major lessons from previous reviews. Section 4 thus reviews previous PES assessments, both comparative case studies and meta-analyses, covering various sector and country contexts. Section 5 summarizes, discusses key insights, and identifies future research needs.

2. A THEORY OF CHANGE FOR EFFECTIVE PES OUTCOMES

By directly compensating environmental service providers for the opportunity costs of conservation, PES was originally conceived as a theoretically cost-effective[2] instrument for maximizing the impact of scarce conservation funds (Ferraro & Kiss, 2002; Ferraro & Simpson, 2002). Still, PES programs—especially in low-income countries—often have the dual objectives of conservation and improved economic and social welfare.[3] Here we review the theoretical predictions of the extent to which a given PES program will deliver upon multiple promises. We assess factors determining the environmental effectiveness and welfare implications of PES programs.

Environmental effectiveness is defined as the change in provision of services induced by the program, compared to a counterfactual without PES. Effectiveness will be determined by four main factors. First, program costs—i.e., transaction and implementation costs net of PES transfers—which determine the number of contracts that can be offered for a given program budget and payment level. Second, the direct changes in land/resource-use among participants induced by the program, compared to a baseline of "no PES" (i.e., *additionality*). Third, the indirect effects (positive or negative) of the program on land/resource use and environmental service (ES) provision outside of contracted land (*spillovers*). Fourth, the effects these changes in land/resource-use among participants and non-participants have on the actual provision of environmental services (e.g., the biophysical link between induced behavioral changes in practices and the targeted ES). Each of these factors is, in turn, shaped by the interplay of features related to the context, design, and implementation of PES (Engel *et al.*, 2008; Persson & Alpizar, 2013) that are discussed below. See Figure 1 for an overview.

Just as with environmental effectiveness, the impact of PES on welfare will be determined by a range of socio-economic and environmental factors (see Figure 1). The most important of these factors are highlighted below, ending with a discussion on the potential trade-offs and synergies between environmental and welfare-related outcomes in PES.

(a) *PES program costs*

Any cost of PES implementation above the minimum payment necessary to induce landowner participation in the PES program will indirectly reduce the environmental effectiveness of the program through a reduction in the number of PES contracts that can be secured for a given budget (Ferraro, 2008). This effect will not be captured by impact evaluations of PES, as these usually only measure the effect of the contracts actually made.

Information rents[4] captured by ES providers can potentially reduce program cost-effectiveness significantly. Just like adverse participant selection, information rents result from a basic information asymmetry: ES buyers do not have (perfect) information on the opportunity and transaction costs associated with PES enrollment, and hence payments will tend to overcompensate ES providers. Under uniform payments, there will be efficiency losses due to information rents even under perfect information about participants' opportunity costs (unless they are perfectly homogenous). Reducing information rents therefore requires differentiating payments to better match ES providers' opportunity costs (Engel, 2016). This can be achieved, for example, based on proxies for opportunity costs (e.g., biophysical land characteristics), screening contracts, or procurement auctions (Ferraro, 2008). The effectiveness gains from payment differentiation will be higher, the larger the heterogeneity in opportunity costs among potential PES participants (Engel, 2016; Wünscher, Engel, & Wunder, 2008). Still, the potential gains have to be weighed against the potential effectiveness losses from increased transaction costs associated with differentiating payments, as well as associated welfare implications.

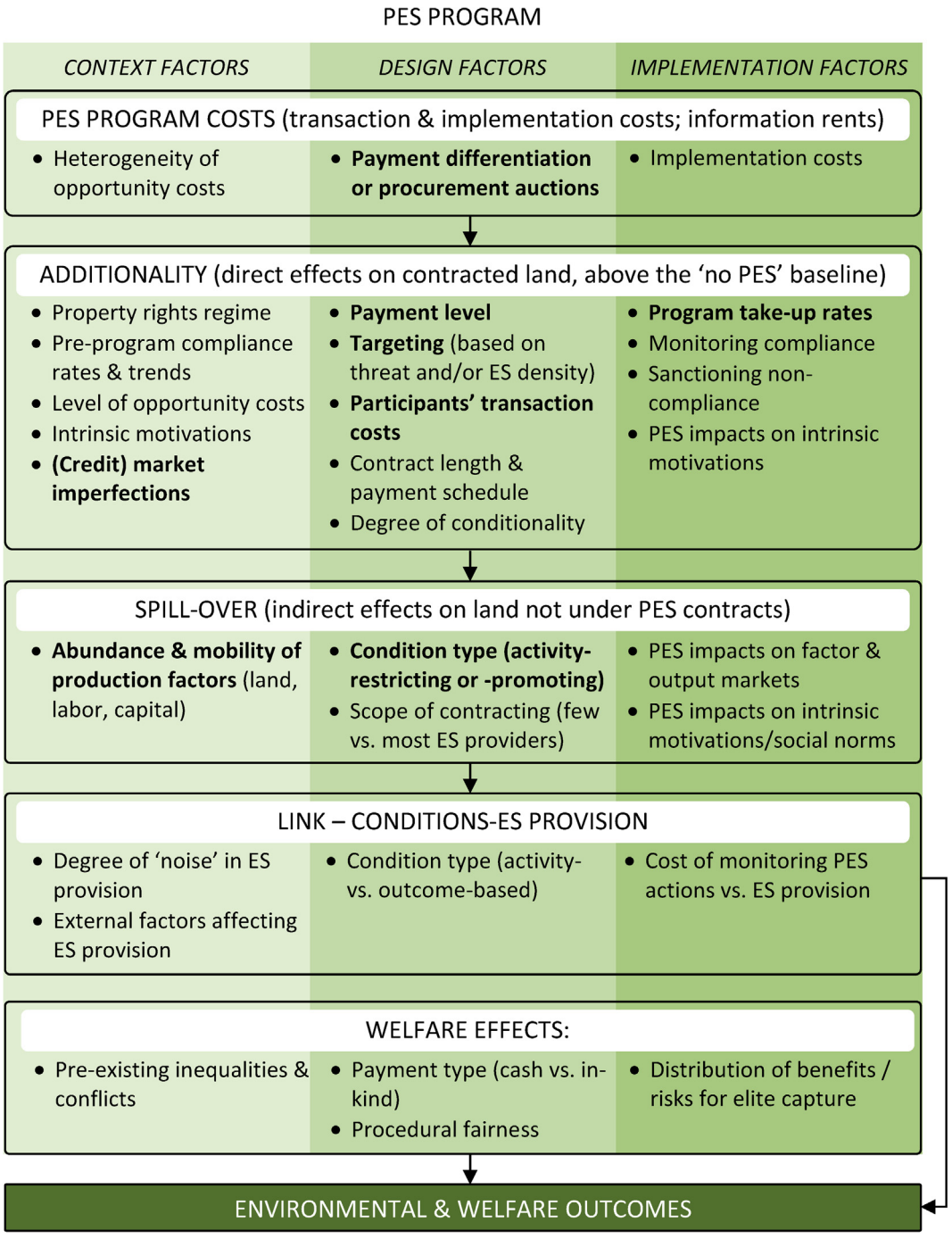

Figure 1. *Theory of change for the factors determining the environmental and welfare effects of a PES program. Factors are organized based on four determinants of environmental outcomes: (1) program costs, which affect the number of PES participants for a given budget and hence (2) the direct impact the program has on participants. Direct effects may in turn result in (3) indirect, or spillover effects. Direct and indirect effects will then determine environmental outcomes through (4) the link between PES program conditions and actual provisions in ecosystem services. For each of these four factors, as well as factors shaping welfare impacts (5), we distinguish between those relating the context (light shading), design (medium shading), and implementation (dark shading) of the program. Factors highlighted in bold are likely to have both environmental effectiveness and welfare implications.*

(b) *Direct program impacts (additionality)*

Adverse participant selection among ES providers is a major source of ineffectiveness in PES implementation. Potential recipients that would have met program conditions even in the absence of payments tend to self-select[5] into programs, and reduce PES additionality. Adverse selection occurs as a result of a basic information asymmetry: program implementers typically do not know whether prospective PES participants will protect or enhance ecosystems services in the absence of payments. Moreover, implementers may pursue multiple policy goals with a PES scheme and thus, whether

intentionally or not, trade off cost-effectiveness against other objectives, such as poverty alleviation (Rosa da Conceição, Börner, & Wunder, 2015).

The prevalence of adverse selection in PES is likely to be especially severe in contexts where pre-program compliance with the conditions for payments is already high, where payments are insufficient to cover the costs of compliance (i.e., due to low payments and high opportunity and transaction costs), and where program take-up rates are low (Persson & Alpizar, 2013). Take-up rates depend on a range of factors affecting the attractiveness of PES, such as the presence of credit constraints or other market imperfections and cultural attitudes (Groom & Palmer, 2010; Jayachandran, 2013), contract length and payment schedule (Engel, 2016), as well as perceptions of fairness and legitimacy (Corbera & Pascual, 2012).

The losses in environmental effectiveness due to adverse selection can be reduced by targeting payments, based on (imperfect) information on ES provision threats and benefits (Engel, 2016). Theoretically, the gains to targeting payments can be substantial (Alix-Garcia, de Janvry, & Sadoulet, 2008; Engel, 2016), but the size of these gains depends on a number of contextual and complementary design factors (Persson & Alpizar, 2013). First, the gains from targeting will naturally be high when potential program participants exhibit large variability in the outcome (e.g., threat of non-compliance, environmental benefits, or opportunity costs) (Engel, 2016; Engel *et al.*, 2008; Ferraro, 2008; Persson & Alpizar, 2013; Wünscher *et al.*, 2008). Second, gains will be higher if program managers target payments based on a combination of proxies for threat, benefit, and opportunity costs (i.e., targeting areas where the provision of high value ES is substantially threatened by land uses with low economic returns) (Newburn, Reed, Berck, & Merenlender, 2005). Third, the gains from targeting will be larger, the higher the adverse selection risk (e.g., high pre-program compliance or low expected take-up rates in the program) (Persson & Alpizar, 2013). Finally, additionality gains from targeting again need to be weighed against increased administrative costs, risks for negative spillovers, and trade-offs with equity and welfare impacts (see below).

Additionality of PES may also be compromised by non-compliance among program participants (moral hazard), especially if monitoring is costly and compliance comes with high opportunity costs (Hanley & White, 2014; Hart & Latacz-Lohmann, 2005). Enforcement of program conditions through monitoring and sanctioning is usually required to achieve high compliance levels, but experimental evidence has also shown excessive control or penalty can reduce the motivation for cooperative behavior, i.e., compliance or participation in the case of PES (Engel, 2016; Falk & Kosfeld, 2006; Vollan, 2008).

Finally, note that any factor raising the minimum payment necessary to induce enrollment in PES will for a given (fixed) budget undermine additionality, since it will mean losing marginal ES providers who are precisely those most likely to offer additional compliance (Figure 2). Apart from providers' opportunity and transaction costs, the PES program itself may either reinforce or erode pre-existing intrinsic motivations for conservation or ES provision (often termed "crowding-in" and "crowding-out", respectively). There are many potential

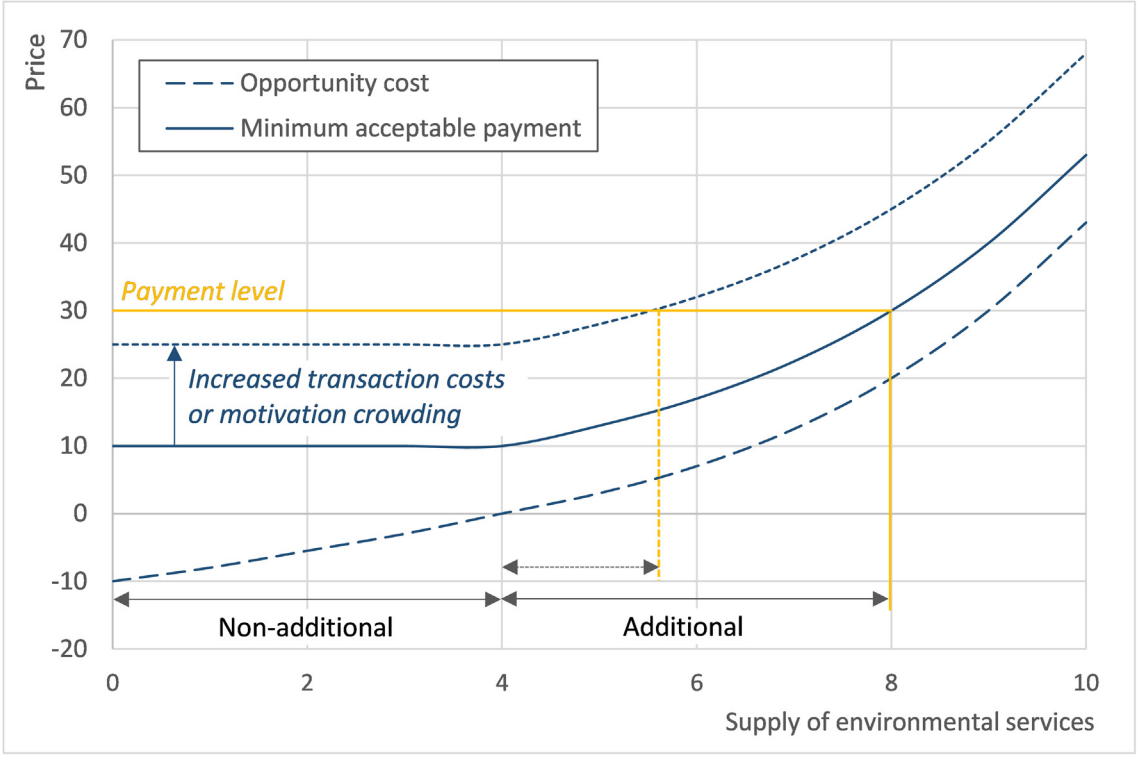

Figure 2. *Hypothetical case for supply of environmental services, where the dashed line represents the opportunity costs of ES supply and the solid line represents the minimum acceptable payment for PES participation. The latter equals the sum of, inter alia, opportunity costs, transaction costs (including risk premiums) and intrinsic motivation for ES provision (for simplicity it is assumed here that the latter two are constant across ES providers). For a given PES payment level (solid, light yellow line) you get a given level of additionality (represented by the share of ES providers with an opportunity cost above zero). Any factor that raises the minimum acceptable payment level (dotted line) will negatively affect PES additionality. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)*

reasons for PES motivation crowding (Rode, Gómez-Baggethun, & Krause, 2015); for example, crowding-in can occur when potential recipients feel that PES is supportive, whereas their motivation can degrade if they feel excessively controlled (Nordén, Persson, & Alpízar, 2013). Crowding-out would reduce providers' willingness to accept PES payments, leading to lower additionality (see Figure 2) and to a reduced likelihood of continued compliance after payments end (*permanence*).

(c) *Indirect program impacts (spillovers)*

Spillovers refer to environmental, social, or economic impacts occurring outside the spatial and contractual scope of a PES scheme, either reducing or boosting its environmental impacts.[6] Most work has focused on environmental spillovers, and often uses other labels for such indirect effects including leakage, slippage, rebound, feedback. We distinguish between spillovers among program participants and non-participants. One can also think of these as within versus between spillovers.

Spillovers among PES participants encompass all ES-relevant actions that are not regulated by PES contracts. First, land owned by participants but excluded from PES contracts may receive additional pressure for resource extraction, as activity substitution occurs (*on-farm leakage*) (Alix-Garcia *et al.*, 2012). Second, increased income from PES may lead to changed household spending patterns, with land-use implications (*rebound*).

The literature has primarily focused on spillovers to non-participants, where PES may induce a displacement of economic activities to land outside the intervention area. For instance, payments for avoided deforestation may reduce employment opportunities for rural workers, who instead move outside project boundaries to colonize and degrade or convert land there. Leakage effects may also work through agricultural product and input markets, raising demand for economic activity elsewhere. For example, cross-boundary leakage may occur when a program increases the international price of resource-extractive commodities, inducing increased activity elsewhere (Sohngen & Brown, 2004). Conversely, a labor-intensive tree-planting program may attract migration of workers, directly or through higher wages, reducing extractive activity outside contracted land (*magnet effects*) (Wittemyer, Elsen, Bean, Burton, & Brashares, 2008).

Leakage effects vary greatly over context, such as the nature of demand for (and supply of) environmental services or products and alternative economic activities (Baylis, Fullerton, & Shah, 2017). For instance, PES-induced restrictions in cash-crop expansion are more likely to generate leakage over space than those restricting subsistence farming, since markets more easily can transfer price signals of increased scarcity for the marketed goods. Figure 3 describes how important contextual factors determine whether an (activity-reducing) PES-style

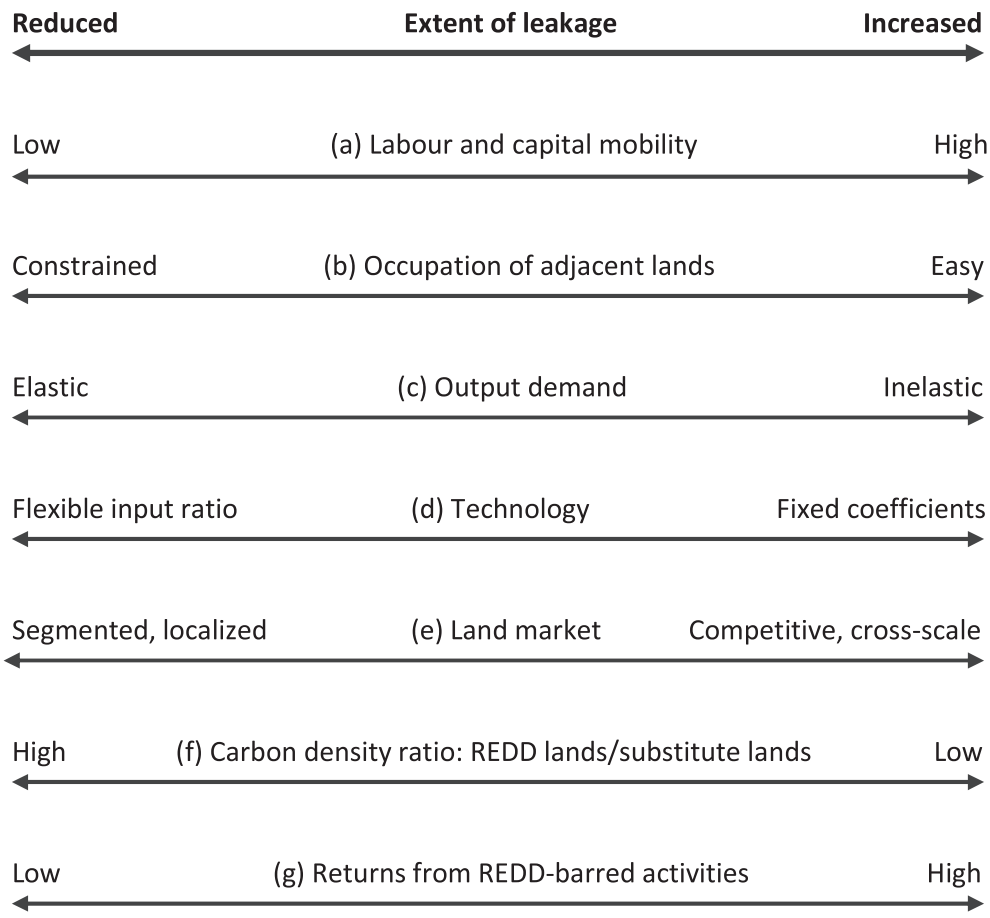

Figure 3. *High vs low REDD leakage scenarios: likely explanatory factors. Source: Wunder (2008a, 2008b). Leakage risk and potential extent depends on the factors labeled from (a) through (g).*

REDD program to conserve forests likely exhibits low or high leakage.

Finally, monetizing conservation may alter the motivation of participants and non-participants, affecting conservation outcomes (Agrawal, Chhatre, & Gerber, 2015; Rode *et al.*, 2015). Motivation crowding can affect the ES provision decisions of land users not contracted in a PES program. Crowding-out, leading to a loss of ES provision outside of the program, is more likely to happen if the program is perceived as unfair, which could be the result of increased targeting based on non-compliance risk to raise additionality (Alpízar, Nordén, Pfaff, & Robalino, 2013) or payment differentiation. Conversely, information spillovers from PES programs could also induce some non-eligible land managers to adopt the targeted conservation practices (Lewis, Barham, & Robinson, 2011).

(d) *Link between program conditions and ES provision*

The choice between paying ES providers for certain actions (e.g., not clearing forests) or observed proxies for ES provision (e.g., forest cover maintained), rather than actual outcomes in terms of ES provision (e.g., additional tons of carbon stored) can strongly influence PES effectiveness (Gibbons, Nicholson, Milner-Gulland, & Jones, 2011; Hanley & White, 2014; Zabel & Roe, 2009). The benefits of paying for outcomes rather than actions are higher the more uncertain are the linkages between the two. Often land users know best which among alternative use options can be adopted at least cost. In such cases, paying for outcomes enables program participants to choose the activity that most cost-effectively increases ES provision (Hanley & White, 2014; Zabel & Roe, 2009). Moreover, paying for outcomes may also decrease the risk for moral hazard, in cases where monitoring the actions of program participants is costly (as discussed above).

However, the perceived drawbacks of conditioning payments on outcomes have so far widely precluded this design option: by far, in most existing PES programs, compliance is based on land-use proxies and other management actions or conditions (see PES reviews in Section 3). There are several reasons for this program choice. First, measuring ES provision may be more costly than measuring actions (e.g., measuring forest conservation is easier than estimating the carbon, biodiversity or water services delivered by targeted forests). Second, if the provision of the ES is dependent on factors external to the provider (e.g., neighbor actions, climate), outcome-based contracts increase the risk for the provider, and may decrease participation (Hanley & White, 2014; Zabel & Roe, 2009). To compensate, programs may then have to offer providers a risk premium (Hanley & White, 2014) (lowering additionality; see Figure 1).

Whether action or outcome-based payments are more cost-effective is thus an empirical question, with payments for outcomes tending to be more cost-effective when: (a) actions are more costly to monitor than outcomes (e.g., rules to restrict the use of fertilizers to preserve water quality may be more expensive to monitor than water quality itself); (b) the effort required for increasing ES provision is high (e.g., reforestation or afforestation schemes); (c) risk-aversion among participants is low (e.g., non-poor ES providers); and (d) ES provision is predominantly influenced by participants as opposed to external factors, such as climate (Gibbons *et al.*, 2011; Hanley & White, 2014; Zabel & Roe, 2009). It is also possible to develop contracts that distribute risks between ES providers and buyers through a combination of action- and outcome-based conditions (Hanley & White, 2014).

(e) *Welfare impacts and their links to environmental effectiveness*

As noted, the theoretical literature analyzing the determinants of social outcomes of PES programs is thin (the empirical literature, reviewed in subsequent sections does, however, provides some evidence). Still, from the discussion above it should be obvious that there are links between factors affecting both environmental outcomes and welfare: maximizing environmental impacts requires a design that affects who gets paid and how much (e.g., targeting and differentiating payments). As "neither the community that fully safeguards its environment nor the impoverished farmer too poor to do much damage" (Wunder, 2007: p. 53) constitute a credible conservation threat, maximizing program additionality may sometimes involve targeting payments to more capitalized, well-off, title landholders, suggesting a trade-off between environmental effectiveness and equity considerations. A second trade-off is in determining the payment size: from an effectiveness point of view, the service provider's surplus (payment minus provision costs) should be minimized, but this would also minimize poverty alleviation impacts.

There are good arguments for not treating environmental and equity goals as fully separate objectives. Disregarding equity aspects entirely in PES design and implementation, i.e., focusing solely on environmental effectiveness, may undercut the credibility of PES schemes, and undermine ES provision in the long run (Corbera & Pascual, 2012; Pascual *et al.*, 2014). As shown by Alpízar *et al.* (2013), targeting payments for maximum additionality could lead to negative behavioral spillovers due to perceived unfairness among excluded PES applicants. Conversely, despite demonstrated tradeoffs between targeting both poverty alleviation and conservation outcomes (Alix-Garcia, Sims, & Yañez-Pagans, 2015), designing a PES scheme that is not additional but legitimate and fair can eventually crowd-in conservation motivations across enrolled and non-enrolled farmers (Martin, Gross-Camp, Kebede, McGuire, & Munyarukaza, 2014). Hence, beyond equity in outcomes, procedural fairness in PES design can potentially promote synergies between equity and environmental outcomes resulting from increased program legitimacy, local buy-in and compliance (Pascual *et al.*, 2014).

3. EMERGING EVIDENCE FROM PES EVALUATION STUDIES

While still in its early stages, there is a growing empirical literature on the effectiveness of PES programs (see also, Samii, Lisiecki, Kulkarni, Paler, & Chavis, 2014). The impact evaluation literature has predominantly focused on how well PES has delivered environmental outcomes and increasingly adopts more sophisticated evaluation methods and empirical strategies. Impact evaluation distinguishes itself from other types of evaluation in that it aims to measure program impacts through the identification of a counterfactual, i.e., what would have happened in the absence of the program. The evaluated outcomes are often proxies of actual environmental services, such as forest cover, through which programs aim at achieving additional service provision (e.g., carbon sequestration).

If program enrollment were randomized among potentially interested participants, program impacts could be measured by comparing outcomes in treatment and control groups using standard statistical procedures. In the past, however, most PES programs were rolled out based on administrative, oper-

ational, or political criteria, leading to systematic differences between participants and non-participants (see previous section). Further, because participation is voluntary, participants and non-participants are likely to differ in terms of observable and unobservable characteristics, which, if correlated with the behavior or ES provision, will bias the estimate of program effect. Various statistical techniques exist to correct for selection bias in such evaluation settings, with matching being one of the most frequently used approaches (Börner *et al.*, 2016).

Below we review studies that have used such experimental and quasi-experimental designs. Table 1 summarizes these studies in terms of regional focus, methodological approach, and main finding. Since the studies used different outcome variables, effect sizes are not directly comparable. Moreover, large effects do not necessarily imply large impacts. For example, the impact of a 50% reduction in deforestation may be rather small if annual forest loss is less than 1% of forest cover. Few studies provide sufficient information to calculate standardized effect sizes. The last column in Table 1 thus provides a qualitative judgement about the actual impact of the evaluated programs.

(a) *Empirical studies of PES effectiveness*

Sanchez-Azofeifa, Pfaff, Robalino, and Boomhower (2007) published one of the first quantitative evaluations of the Costa Rican national PES program that focused on the forestry sector. Using OLS regression analysis, the authors found little impact of the program and hypothesized that the observed drop in deforestation rates was probably due to other conservation initiatives, not PES. They also suggested that adverse selection led to the enrollment of land with low conservation opportunity costs in which deforestation was unlikely; a notion that other studies on program participants have confirmed (Arriagada, Sills, Pattanayak, & Ferraro, 2009; Hartshorn, Ferraro, Spergel, & Sills, 2005; Robalino & Pfaff, 2013).

Alix-Garcia *et al.* (2012) conducted a counterfactual-based impact evaluation of the national PES program in Mexico. The National Payment for Hydrological Services program targeted forest conservation in hydrologically important watersheds. The authors quantified the reduced deforestation in the 2004 program cohort by drawing from an oversubscribed applicant pool of the same year as their controls. Rejected land-owners from the same applicant pool are arguably similar to approved applicants especially with regard to motivation since both owner groups demonstrated a similar interest in participating in the program. The study found that deforestation rates were 50% lower in enrolled parcels, but that deforestation rates were generally low, which suggested that potential additionality was limited to begin with.

During this early period of PES impact evaluation, multiple small-scale programs were developed around the world, but few initiatives collected data on both pre-treatment conditions and a relevant control group. A small-scale PES program, designed to protect forest cover in Veracruz, Mexico, is a notable exception. With data on forest cover before and after the program, on enrolled and non-enrolled forest plots, Scullion, Thomas, Vogt, Pérez-Maqueo, and Logsdon (2011) assessed program impacts using a difference-in-difference approach. Their results suggested a 30% reduction in deforestation among PES participating communities. However, based on complementary qualitative assessments, the PES program was only one among other factors affecting land-use decisions.

Low effectiveness at the country level notwithstanding, PES schemes can be effective at the local scale. Evaluating a biodiversity PES program in the southern state of Chiapas, Mexico, where pressure on forest resources has been historically high, Costedoat *et al.* (2015) found that during 2007–13, payments avoided 12–15% forest cover loss in participating PES communities. Similarly, Honey-Rosés, Baylis, and Ramírez (2011), using spatial matching and difference-in-difference analysis found that forest use restrictions coupled with a PES for forest conservation in the Monarch Butterfly Biosphere Reserve, an area with relatively high deforestation rates in central Mexico, lead to significantly lower forest loss and degradation. Similarly encouraging findings of effective PES at the local level have been published for the Costa Rican PES program (Arriagada, Ferraro, Sills, Pattanayak, & Cordero-Sancho, 2012).

PES has also been shown to work effectively in industrialized and other developing country contexts. A matching study by Pufahl and Weiss (2009), for example, found the European agri-environmental program to have induced German farmers to significantly reduce cultivated area and agro-chemical use. Similar studies have been conducted for the US Conservation Reserve Program, suggesting varying levels of additionality for eligible agricultural practices, for reasons related to baseline compliance and adverse selection (Claassen, Duquette, & Horowitz, 2013).

Jayachandran, de Laat, Lambin, and Stanton (2016) conducted the first impact evaluation of a PES program using a randomized controlled trial. The study evaluated the impact of forest conservation contracts in randomly selected treatment and control villages in western Uganda, where deforestation was historically high. After program implementation, estimated forest loss ranged from 7% to 10% in control villages and from 2% to 5% in treated villages, a reduction of approximately 50%. Program cost estimates at USD 0.97 per ton of avoided carbon dioxide emissions also point to PES having been a cost-effective climate change mitigation option in this particular case. Also in Africa, Hegde and Bull (2011) used propensity score matching to estimate the impact of an asset-building agroforestry PES program in Mozambique and found participant households exhibited lower crop yields and forest product extraction than non-participant households.

A common concern about PES programs is the long-term impact when payments are discontinued. Pagiola, Honey-Rosés, and Freire-González (2016) examined this issue following the termination of a four-year PES program that paid ranchers in Colombia to adopt silvopastoral practices that had biodiversity benefits. They found that even though payments had ceased years ago, the positive land use changes were maintained. Unlike PES programs that pay for conservation, this program provided incentives, and in some cases technical assistance, to adopt new practices, rather than merely conserving existing land uses by restricting resource use. To our knowledge, no such long-term evaluation has yet been conducted in a context of avoided loss of environmental services, where we would, all else equal, not expect permanence without payment. Clearly, more empirical evidence is needed to understand the determinants of permanence in PES programs.

Finally, impact evaluations have also acknowledged that PES are only one of a suite of programs and policies used to generate conservation benefits. Hence, some studies have also compared PES to other policy tools, such as protected areas (Robalino, Sandoval, Barton, Chacon, & Pfaff, 2015; Sims & Alix-Garcia, in press) and community forest management (Baylis, Honey-Rosés, & Ramírez, 2012). Sims and Alix-

Table 1. *Summary of Impact Evaluation studies of PES programs*

Authors	Location	Outcome variable	Method	Finding	Impact
Alix-Garcia et al. (2012)	Mexico	Forest cover	Matching	50% lower forest cover loss	Small
Arriagada, Sills, Pattanayak, and Ferraro (2009)	Costa Rica	Income and welfare indicators	Matching	No impact	None
Arriagada et al. (2012)	Sarapiquí, Costa Rica	Forest cover	Matching	PES increases forest cover by 11–17%	Large
Baylis et al. (2012)	Monarch Reserve, Mexico	Forest Cover	Matching	PES improves outcomes of forest management and legal protection	Small
Claassen et al. (2013)	United States	Adoption of conservation practices	Matching	High for structural practices; modest for nutrient management	Large
Costedoat et al. (2015)	Chiapas, Mexico	Forest cover	Matching	Additional forest conservation of 12–14%	Large
Hegde and Bull (2011)	Mozambique	Welfare measures	Matching	Increased cash income and consumption	Small
Honey-Rosés et al. (2011)	Monarch Reserve, Mexico	Forest cover	Matching	Protected 200–710 ha of high quality habitat but smaller effect on reduced deforestation 0–200 ha	Small
Jayachandran et al. (2016)	Uganda	Forest cover	Randomized Controlled Trial (RCT)	50% reduction in forest cover loss	Large
Pagiola et al. (2016)	Colombia	Environmental services index	OLS	Environmental gains permanent years after PES payments stop	Medium (long-term)
Pufahl and Weiss (2009)	Germany	Agricultural intensity	Matching	Increase in grassland area, reduction in livestock density and purchased agricultural chemicals	Medium
Robalino and Pfaff (2013)	Costa Rica	Forest cover	Matching	0–0.2% annual increase in forest cover	Small
Robalino et al. (2015)	Costa Rica	Forest cover	Matching	Higher additionality of PES if implemented away from protected areas	Small
Scullion et al. (2011)	Veracruz, Mexico	Forest cover	Difference in Difference	30% reduction in deforestation	Large
Sanchez-Azofeifa et al. (2007)	Costa Rica	Forest cover	Regression	No impact	None
Sims and Alix-Garcia (in press)	Mexico	Forest cover, Poverty alleviation index	Matching	25% reduction in forest cover loss 10% increase in poverty alleviation index	Medium (forest cover) Small (poverty alleviation)
Uchida et al. (2007)	China	Income, assets	Regression	No significant effect on income, positive effects on assets	Medium

Garcia compared PES to protected areas across all of Mexico and found that both interventions have reduced forest cover loss by 20–25%, whereas in Costa Rica, Robalino and collaborators found PES to have little additionality in and around protected areas. Baylis and colleagues explored the interactions among the three policies in a relatively small region in Mexico. Their study finds that virtually all benefits from PES come from communities who had adopted forest management earlier, i.e., PES outcomes were leveraged through community training and involvement during the implementation of community forest management.

(b) *PES effects on welfare*

In early work on welfare outcomes of PES, Uchida, Xu, Xu, and Rozelle (2007) evaluated the effect of China's sloping land conversion program on income and find that the program, although participation was allegedly not always strictly voluntary, had been moderately successful in benefiting the poor, primarily through income from livestock activities and increases in asset holding (see also, Liu, Lu, & Yin, 2010).

Arriagada, Sills, Ferraro, and Pattanayak (2015) examined the welfare impacts of Costa Rica's PES program using a subnational set of household survey data. They found no significant effect on income and welfare indicators for households participating in the PES program during the 1996–2005 period, perhaps because of the program's selection bias toward participants with a comparatively favorable socio-economic profile (Zbinden & Lee, 2005). Similarly, in Mexico, Sims and Alix-Garcia (in press) found that PES payments have had small effects on reducing poverty, even though the payments are non-trivial relative to household budgets. In the Mozambican PES scheme, however, Hegde and Bull (2011) found significant effects on household consumption expenditure and cash incomes, especially among poor households, whereas Uchida *et al.* (2007) found positive effects of China's Grain for Green Program on asset wealth.

(c) *Key messages*

It is still too early to draw externally valid conclusions from the young field of PES impact evaluation: few rigorous studies have been undertaken, and in addition those are too concentrated on a small number of countries (e.g., Costa Rica, Mexico). However, the findings of the studies reviewed above broadly correspond to the theoretical predictions identified in the previous section. Evaluations of PES in settings with high levels of baseline compliance and potential for adverse selection (e.g., country level programs in Mexico and Costa Rica) exhibit low average levels of effectiveness. This does not preclude subnational scale PES initiatives from being effective, for example, in high-pressure settings with low baseline compliance (e.g., Chiapas, Monarch Butterfly Biosphere Reserve). The evidence-base for the socio-economic benefits from PES is weak, but among the three reviewed studies no negative effects welfare effects were found and significant benefits accrued in the Chinese and Mozambican case, where the potential to increase welfare levels was high among eligible households.

4. LESSONS FROM PES REVIEWS

This section synthesizes peer-reviewed studies that document lessons from PES programs at national, regional, and global scales. The nature of this review literature has changed over time, reflecting the evolving theoretical debate (see Section 2). An overview of the studies discussed below is given in Table 2 highlighting scope, approach, and key findings of each review. Until about 2013, many authors used narrative-based analyses of PES programs with a specific geographic or sectorial focus. Many of these early reviews focused on payments for watershed services in developing countries, with occasional studies also looking at payments for carbon forestry and biodiversity conservation. Wunder, Engel, and Pagiola (2008) broadened the scope to encompass programs in both industrialized and developing countries that promoted various types of ES. Since 2013, reviews have increasingly adopted quantitative-comparative analyses including multi-criteria classifications to explore issues identified in the theoretical PES literature, such as ecological and social program effectiveness and effectiveness-equity trade-offs (see Section 2). Overall, these reviews offer important insights as to how contextual factors and program design can determine outcomes in terms of environmental performance, cost-effectiveness and social outcomes.

(a) *Evidence on PES effectiveness*

Early PES reviews tended to focus on watershed-based programs since these dominated the portfolio of PES programs in developing countries. These reviews generally showed that low willingness to pay among poor service users, state control of environmentally sensitive lands, high transaction costs, or weak institutions and organizational capacity among both service providers (e.g., tenure insecurity) and users (e.g., monitoring and enforcement infrastructure) are key obstacles for the adoption and environmental effectiveness of PES (Ferraro, 2009; Huang, Upadhyaya, Jindal, & Kerr, 2009; Martin-Ortega, Ojea, & Roux, 2013; Southgate & Wunder, 2009). Reviewing 37 cases of payments for biodiversity conservation projects in developing countries funded by international donors, Milne and Niesten (2009) further emphasized the importance of local participation in PES design, the recognition of cultural values, and the social responsibility of involved actors. They also identified a number of conditions that, if present, will impede PES development or limit their future effectiveness, including longstanding tenure conflicts, unidentifiable or unavailable service providers, or unacceptable social impacts and high implementation risks (see also, Pagiola, Rios, & Arcenas, 2008; Wunder, 2008a, 2008b).

Taking stock of a diverse set of PES experiences in both developing and industrialized countries, Wunder, Engel, and Pagiola (2008) observed that program design and performance often differ between user-financed and government-led initiatives. At the time, only one of the reviewed initiatives adopted an approach to measure additionality compared to *ex-ante* scenarios. User-financed programs, characterized by a smaller scale and a single ES focus, were more often found to adopt targeting criteria and strong conditionality rules than government programs. Preliminary evidence correspondingly also seemed to suggest higher effectiveness for such user-led programs. The study further observed that many PES programs lacked evidence on the impact of land-use practices on the desired ecosystem services and had often been established on "shaky scientific background" (pp. 846; see also Huang *et al.* (2009)).

More recent reviews squarely focused on the relationship between PES design principles and environmental effectiveness. Classifying 22 PES cases in Germany and the US according to multiple-criteria, Sattler, Trampnau, Schomers, Meyer, and Matzdorf (2013) substantiated some of the additional

Table 2. *Summary of PES review studies*

Source (Year)	Objective and relevance	Methods	Key findings & implementation gaps
Wunder et al. (2008)	To compare PES experiences in low-and high-income countries, distinguishing between government and user-financed initiatives First comparative analysis linking design features with potential environmental outcomes	Narrative synthesis of peer-reviewed analyses of the PES experiences	User-financed PES tend to more efficiently reach added ES provision through more adequate targeting and stronger enforcement of conditionality Need to systematically collect ecological and socio-economic data to draw more conclusive lessons on outcome
Jindal et al. (2008)	To identify challenges and risks in the implementation of carbon forestry, as well as to suggest possible avenues for improvement and scaling-up First comparative analysis of carbon forestry experiences.	Narrative synthesis of secondary data from 23 carbon-forestry projects in Africa	Evidence of positive impacts on carbon sequestration and participants' income Potential risks related to the conversion of grasslands, land tenure insecurity and high transaction costs Opportunities related to strengthening forest governance and community institutions Lack of data on social-ecological indicators to support project design, monitoring and evaluation
Milne and Niesten (2009)	To identify design needs and implementation challenges of payments for biodiversity conservation initiatives in low-income countries First comparative analysis of biodiversity payments in low-income countries, with a focus on the interaction between design factors and project success	Narrative synthesis of secondary data from 37 projects funded by Conservation International	Need to mainstream impact evaluation methods, participatory approaches to both design and implementation, clarify tenure rights, strengthen local governance institutions and ensure the legitimacy of payment contracts
Huang et al. (2009)	To review and characterize the implementation of payments for watershed services in Asia First comparative analysis of payments for watershed services in Asia and an analysis of scaling-up constraints	Narrative synthesis of peer-reviewed and secondary data from 15 experiences	Most initiatives are government-led and/or – funded Conditionality is weakly enforced and participation in some initiatives is mandatory rather than voluntary Projects lack evidence on ES supply levels and poverty alleviation
Ferraro (2009)	To review existing initiatives of payments for watershed services in Africa First comparative analysis, including of scaling-up constraints	Narrative synthesis of peer-reviewed and secondary data from two on-going and six planned initiatives	Existing and planned initiatives focus on poverty alleviation at the expense of a careful ES targeting and provision Financing based on taxes; small involvement of end-users Explanatory causes of the slow emergence of payments for watershed initiatives in Africa include a limited involvement of non-governmental actors, high transaction costs, land tenure insecurity, and weak resource governance
Southgate and Wunder (2009)	Overview of payments for watershed services in Latin America and in-depth review of three initiatives in order to identify implementation challenges First in-depth, comparative analysis of three watershed payments initiatives in Latin America.	Narrative synthesis of peer-reviewed and secondary data focused on the reviewed initiatives.	Reviewed initiatives are characterized and challenged by: modest environmental benefits, determined by natural environmental variability, limited scientific evidence, and non-compliance; high conservation, start-up and recurrent costs, which are often not covered with buyer-provider transactions alone; and lack of governmental involvement in monitoring efforts, which would ease recurrent costs

Brouwer, Tesfaye, and Pauw (2011)	To analyze the relationship between the design factors of payments for watershed services and their environmental effectiveness First meta-analysis of payments for watershed services worldwide	Logistic regressions between design factors and environmental effectiveness indicators across 47 payments for watershed services initiatives, drawing on secondary data plus a targeted email questionnaire	Payments are more likely to be environmentally effective if they are user-led, obligatory rather than voluntary, have a minimal number of intermediaries, count with community/collective support and enforcement, and if their environmental objectives are carefully quantified and monitored
Martin-Ortega et al. (2013)	To identify environmental compliance, implementation challenges and deviation from theory of payments for watershed services in Latin America Development of conceptual model to support better design, implementation and monitoring	Analysis of peer-reviewed literature of 40 initiatives in Latin America, drawing on key design and implementation variables to develop a descriptive analysis	Initiatives are characterized by low or non-existent conditionality, a poor definition and monitoring of the ES being paid for, and payments are not based on robust calculations of opportunity costs—or any other valuation approaches—and rather set through negotiations among participants
Schomers and Matzdorf (2013)	To illustrate the different analytical perspectives on PES concepts and types, the foci of PES research and to identify differences and similarities in conservation programs and main research topics between low- and high-income countries	Analysis of 457 peer-reviewed articles focused on PES conceptual and empirical debates, using a set of pre-defined categories	PES publications mostly focus on Latin America, Asia and/or Africa experiences. PES schemes rarely follow a Coasean approach and they more frequently resemble Pigouvian or Environmental Pricing and Standards approaches. National PES programs in the EU and the USA—often no labeled as PES—and LA resemble in most of its characteristics
Sattler et al. (2013)	To develop a multi-classification system for PES as a helpful tool to systematically characterize PES approaches, and to apply such system to the analysis of selected PES cases Comparative analysis investigating which PES characteristics are related to the overall success of PES schemes	In-depth comparative analysis of 22 allegedly successful PES cases from Germany and USA, using descriptive variables from secondary data	Positive PES outcomes are positively associated with the involvement of an intermediary and a government actor, voluntariness, contract length and the presence of co-benefits
Hejnowicz et al. (2014)	To investigate PES programs in terms of their social, environmental, economic and institutional outcomes, focusing on efficiency, effectiveness and equity trade-offs Development and use of a capital assets framework to analyze multi-dimensional trade-offs	Comparative analysis of 44 PES cases, using descriptive variables derived from the capital assets framework, and based on peer-reviewed publications from the selected cases	PES are heterogeneous in terms of design characteristics, and their implementation is characterized by a lack of: protocols for assessing ES production and distribution; and adequate accounting tools for social, human and institutional outcomes Need to connect land-use practices and ES provision; adequately contribute to livelihood development by focusing on the poorest sectors; and to build institutional capacity and institutions that are robust, inclusive, transparent and accountable
Calvet-Mir et al. (2015)	To examine the effectiveness and equity-related performance of PES initiatives targeting biodiversity conservation in tropical and sub-tropical countries, distinguishing across analytical and methodological approaches Identification of future PES research areas, based on the reviewed articles' analytical and methodological gaps	Narrative synthesis of 34 peer-reviewed articles analyzing 29 initiatives of PES in tropical and sub-tropical countries	Positive impacts of PES on environmental effectiveness are more frequently confirmed than for equity, while additionality is lower in forest conservation PES programs implemented in areas with low levels of deforestation Trade-offs across these two dimensions are rarely explored in a single study in a quantifiable manner PES enabling conditions include: "locally-suitable" PES practices and payments, inclusive land access relations, and long-term commitment by PES implementers

Table 2 (Continued)

Source (Year)	Objective and relevance	Methods	Key findings & implementation gaps
Grima et al. (2016)	To analyze PES initiatives in Latin America, characterizing their which pre-determined criteria result more important to explain a particular outcome Development and use of a multi-criteria framework to identify PES design factors and implementation performance	Comparative analysis of 40 PES cases in Latin America, using descriptive variables from a multi-criteria framework.	Direct PES schemes, mid-term (10–30 yrs), in-kind payments and well-defined ES are associated with positive environmental compliance and additionality Unsuccessful PES schemes can be explained by investors' perception of no-added value, payments not covering opportunity costs, livelihoods not improving, and unfair decision-making and benefit-sharing.
Ezzine-de-Blas et al. (2016)	To identify global typologies of PES initiatives and the key design factors that determine environmental additionality Robust quantitative and statistical analysis of a large sample of PES initiatives across the world	Meta-analysis of the peer-reviewed literature published on 55 case studies worldwide	Typologies of PES around the world cluster around the type of economic sector involved and ES, although such clusters are not robust predictors of additionality PES initiatives with pre-defined spatial targeting, payments' differentiation and supporting asset-building (e.g. added environmental value, rather than avoiding projected damage) more frequently found to result in additionality

conjectures of the Wunder, Engel, and Pagiola (2008) and earlier reviews: positive environmental outcomes are associated with the involvement of trustworthy intermediaries, sufficiently long contracts, social co-benefits (well-being, public image) and voluntary participation. Growth in the peer-reviewed PES literature soon allowed constructing global datasets of PES cases, which Grima, Singh, Smetschka, and Ringhofer (2016) and Ezzine-de-Blas *et al.* (2016) analyzed to study potential determinants of PES performance. Based on descriptive comparative analysis, Grima *et al.* (2016) find that medium term (i.e., 10–30 years duration) PES schemes, using in-kind payments for well-defined ES, are most frequently associated with simple measures of environmental additionality. Using categorical principal component analysis Ezzine-de-Blas *et al.* (2016) clustered a global dataset of PES initiatives into three sectorial groups: public, private for-profit and NGO-led schemes. They subsequently ran a logistic regression of a binary additionality measure on design factors, such as the degree of spatial targeting (on ecosystem service density and degradation threat), enforcement of conditionality (through monitoring and sanctioning), and differentiation of payments, confirming their positive contribution to environmental effectiveness. The sectorial clusters (public, for-profit, NGO) were non-significant predictors of additionality, but asset-building schemes, perhaps due to lower baseline compliance levels and outcome observability, were more strongly associated with additionality than conservation PES.

(b) *Tradeoffs*

Many of the above-cited PES reviews have also discussed various types of conflicts of interest in PES, such as tradeoffs between environmental and social development objectives or the negative ecological effects that might result from targeting a specific ES. While the latter tradeoff may be specific to PES as a tool to promote the provision of selected ES with a defined group of beneficiaries, social tradeoffs could potentially be PES-specific, but have also allegedly characterized a much broader spectrum of environmental policy tools (Ferraro & Hanauer, 2011).

Reviewing the implementation of 23 carbon forestry projects in Africa, Jindal, Swallow, and Kerr (2008) raised concerns about ES tradeoffs when PES programs focus on the provision of a single service, such as carbon sequestration through forest plantation initiatives, at the cost of losing non-targeted services, such as biodiversity-related services in savannah landscapes. Building on the capital asset framework (with human, social, natural, financial, and institutional dimensions) and reviewing 23 PES initiatives included in 44 peer-reviewed studies, Hejnowicz, Raffaelli, Rudd, and White (2014) produced descriptive evidence for the potential of PES programs to enhance win–win and win-lose outcomes in terms of environmental effectiveness and welfare-related outcomes. Data gaps prevented the authors from establishing causal relationships between intervention context, design, outcomes, and tradeoffs in terms of capital assets.

With a specific focus on exploring effectiveness-equity performance and trade-offs, Calvet-Mir, Corbera, Martin, Fisher, and Gross-Camp (2015) examined 34 studies analyzing 29 PES schemes for biodiversity conservation in tropical and sub-tropical countries. The reviewed studies relied more frequently on protocols to evaluate environmental effectiveness and thus reported positive impacts on environmental effectiveness more often than equity effects. In line with the predictions in Section 2 the study also noted lower additionality in forest conservation PES programs that are implemented in areas

with low levels of deforestation. The analysis moreover demonstrated that several studies focused on either effectiveness or equity and that trade-offs across these two dimensions are rarely explored in a systematic and quantitative manner. In line with earlier reviews, the study highlighted a number of PES enabling conditions, such as "locally suitable" PES eligible land use options and corresponding payment modalities, inclusive land access relations, and long-term commitment by PES implementers.

(c) *Key messages*

PES reviews have advanced our understanding of existing practice in PES implementation. They highlight key contextual and design factors that limit the potential of PES to achieve effective and socially desirable outcomes, such as inadequate or poorly functioning institutional settings, including property rights issues, lack of a science-base for scheme design, and the importance of implementing agencies. Many of these factors cannot be overcome by PES programs alone and some have escaped the formal theoretical debate about PES (Section 2). PES reviews also identify important gaps in research and practice. PES implementation to date has lacked sufficient grounding on ecological systems thinking and data collection, which should enable practitioners to test the relationship between the PES-induced ecosystem management practices and the targeted ecosystem services. There is a need to move beyond the quantification and analysis of land cover proxies, and incorporate evidence on resulting ecosystem services and potential ecological trade-offs. In this regard, Naeem *et al.* (2015) have recently advocated for the development and application of a series of principles and guidelines for PES implementation, based on four basic ingredients: (i) the collection of baseline data; (ii) the monitoring of key environmental services; (iii) recognizing the dynamic nature of ecosystems; and (iv) the inclusion of metrics (specifically on risks such as climate change or invasive species).

Another gap concerns the tradeoffs between PES ecological performance and social outcomes, including equity-related aspects (i.e., recognition, fair participation and distribution of net PES benefits). There are both context-mediated positive and negative feedback loops between social and ecological outcomes in PES implementation, and equity should figure centrally in design and implementation if interventions are to be sustainable over time. However, research exploring such feedback loops in PES practice is not yet available, and corresponding guidelines have not yet been developed.

5. CONCLUSIONS

We have reviewed the PES literature with a focus on the theoretical predictions, as well as qualitative and quantitative studies of the effectiveness of PES in achieving additional ES provision and socio-economic benefits. Our theory of change highlights the role of implementation contexts and policy design in determining the environmental and socio-economic outcomes of PES initiatives. Many contextual factors that are conducive to cost-effective PES, such as low levels of pre-program compliance and opportunity costs, well established property rights, and limited mobility of production factors, will also favorably affect the performance of alternative environmental policy tools. PES, however, is particularly demanding with respect to the exclusiveness of rights to land on the provider side, which represents a barrier to upscaling payment-based policies particularly in low-income countries.

And yet, PES is fundamentally different from conventional environmental policy instruments in operating through incentives rather than disincentives like legal regulations, sanction mechanisms, or taxes. This inherent incentive feature is both its virtue and its major challenge. If well-designed, payments can be a least-cost *Pareto* efficient solution to correct market failures. However, poor design could lead to wasted financial resources and potentially adverse environmental or social outcomes, for example, through unintended effects on human behavior. In many aspects, PES is thus a demanding policy tool that can synergistically complement environmental policy mixes if carefully designed and implemented in appropriate contexts.

Our review of the emerging PES impact evaluation literature (Section 3) highlights various stories with significant positive impacts on environmental outcomes (primarily at local or subnational scale). Often environmental impacts are small (especially among national level programs) though not necessarily smaller than the impacts of other conservation policy instruments, such as protected areas, in comparable contexts (see Börner *et al.*, 2016). The few evaluation studies that addressed social outcomes of PES have found small positive effects at best, but also no negative impacts. Readers should note, however, that this literature is still far from representing a systematic evidence base that would allow drawing externally valid conclusions about PES. Large differences exist with regard to data quality and availability across PES initiatives (especially small user financed schemes) and the existing set of studies is probably biased toward the small number of schemes that have been operational long enough to produce measureable results (Börner *et al.*, 2016). The available evidence, nonetheless, makes PES look neither worse nor much better that other conservation policy tools.

Our analysis of PES review studies (Section 4) indicates that the contextual factors and design principles identified in our theoretical review (Section 2) tend to matter greatly in practice. Many PES programs exhibit high pre-program compliance rates and suffer from adverse selection bias. Many programs are also poorly aligned with pre-existing regulatory policies, ignore the potential for targeting payments, or fail to implement appropriate monitoring and sanctioning mechanisms and social safeguards. Often these programs were judged less successful by the authors of review studies, based on both qualitative and quantitative analyses, than programs that more closely adhered to "best practice" principles.

Moreover, the PES reviews shed light on the potential tradeoffs involved in designing cost-effective payment schemes. Clearly, PES schemes interact with pre-existing social-ecological systems and policy frameworks in ways that are seldom sufficiently well understood. Advances in both theoretical and empirical work on PES and other policy tools are needed to improve our understanding of such interactions and identify strategies to optimally tailor payment schemes to complex intervention contexts.

We acknowledge that both empirical strategies and datasets to evaluate PES initiatives are improving over time, but emphasis has so far been placed primarily on environmental outcomes. Both methods and data collection protocols need to be developed further to allow for the analysis of social-ecological tradeoffs or synergies in PES implementation. To validate theoretical predictions (see Section 2), evaluation research should move beyond measuring average impacts and uncover local context-induced heterogeneous effects, as well as causal mechanisms behind program success (Ferraro & Hanauer, 2014). Like many development programs, new PES schemes should be implemented in a way that is con-

ducive to evaluation, for example, by adopting oversubscription or randomized phase-in strategies. Moreover, insights from behavioral psychology and economics have yet to be harnessed by both PES scholars and practitioners as a strategy to better understand and govern unexpected behavioral responses to incentive-based environmental policy.

Clearly, there are limits to expanding rigorous evaluation schemes in real-word policy contexts and PES reviews have shown to be a useful tool to promote insights from comparative analyses of PES experiences around the world. As the number of initiatives increases along with the collection of standardized data on implementation contexts, scheme design, and early outcome indicators, such reviews can become even more powerful tools for policy advice by adopting more rigorous meta-analysis standards (Ezzine-de-Blas *et al.*, 2016).

6. RECOMMENDED READINGS

Engel, S. (2016). "The devil in the detail: A practical guide on designing payments for environmental services." International Review of Environmental and Resource Economics forthcoming. *Comprehensive overview of issues in the design of PES schemes.*

Ezzine-de-Blas, D., S. Wunder, M. Ruiz-Pérez and R. del Pilar Moreno-Sanchez (2016). "Global patterns in the implementation of payments for environmental services." PLOS ONE 11(3): e0149847. *Global meta-analysis of PES schemes.*

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NOTES

1. Google Scholar search on February 27th (2017), using the following search terms: "Payments for Environmental Services" OR "Payments for Ecosystem Services" OR "Payments for Hydrological Services". For comparison with other environmental policy instruments, the term "protected area" was in about 6100 publications per year during the same period.

2. Here we define (cost) effectiveness as the increase in environmental service provision over the counterfactual without PES that is achieved for a given budget. Efficiency, in turn, refers to the societal benefits of the increased environmental service provision and the associated costs, hence requiring monetary valuation of the environmental services.

3. For example, PES may directly affect the incomes of people living in intervention areas, and thus subsequently on their food security and asset endowments.

4. Rent is the difference between payments for a good or service and its costs of provision. In PES, information rents refer to the possibility that ES providers are paid more than necessary to cover their ES provision costs, since the latter are unknown to program implementers.

5. "Selection" refers to the process of identifying and enrolling participants in a PES scheme, whereas "self-selection" refers to the choice made by participants themselves.

6. We focus on the ES targeted by the program, but note that programs may also induce spill-overs affecting other environmental services (e.g., a plantation for carbon sequestration affecting biodiversity, watershed protection, or recreational values—positively or negatively).

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