Deforestation and Smallholder Income: Evidence from Remittances to Nepal

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ABSTRACT *This article examines the effect of remittance income on deforestation in Nepal during 2001–2010 using satellite-based land use data and a nationwide household survey. Results indicate that remittance income reduced deforestation by 4.2 percentage points, accounting for almost 12% of deforestation during this time. An additional 1,000 Nepalese rupee increase in average household annual remittance income reduced the ward-level deforestation by an approximate 0.435 percentage point. There is no evidence that remittances induced expansion of agricultural land or stimulated demand for forest products. Instead, remittances contributed to the shift of households' demand for timber and fuelwood toward nonwood alternatives for housing construction and cooking.* (JEL Q13, O15)

1. Introduction

The effect of income increase on deforestation is indeterminate (e.g., Angelsen and Kaimowitz 1999; Zwane 2007; Alix-Garcia et al. 2013). Multiple effects and causal pathways underlie this indetermination. Higher income can relax smallholder farmers' liquidity constraints, thereby increasing agricultural revenue via increasing input and investments; higher income also can increase demand for agricultural and forest products. Both effects can impose pressure on forestland. On the flip side, increased income can reduce pressure on forests, for example, by raising the opportunity cost of rural labor force or by replacing firewood with fossil fuel–based energy sources. How these forces interact in determining the income-deforestation relation is an empirical question. Scientific evidence is generally limited because of endogeneity concerns about income growth. As poverty alleviation and environmental conservation have drawn considerable attention from academic scholars and policy makers, an improved understanding of the effect of income increase on forest resources and the underlying mechanisms is clearly needed. This study presents new evidence about this issue by focusing on remittance transfers and deforestation in Nepal.

Nepal is a landlocked country in the transitional zone between the eastern and western Himalayas. The country has rich forest resources and biodiversity: forests and shrubs together covered about 5.83 million ha in the 1990s, nearly 40% of the total land area of the country (DFRS 1999). The country experienced rapid decline in forest stock in the 1980s and 1990s, with a reduction of about 1.7% per year (DFRS 1999). Although the rate of deforestation had significantly slowed since the late 1990s (FAO 1997), partly because of the establishment of the community forestry program (CFP) (Dahal and Chapagain 2008), there was still a considerable forest loss each year. Approximately 7,000 ha of primary forests had been lost in Nepal between 2000 and 2005 (FAO 2006), making

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Nepal eighth among countries with the highest rate of deforestation of primary forests. Most of the cleared land was converted into agricultural use (Appendix Figure A1). Fuelwood collection also added to deforestation. Solid biomass supplied 85% of the energy consumption in Nepal, 6.5 times as much as fossil fuels (WRI 2005). Rural residents, particularly the poor, relied on government forests to fill a large supply gap of fuelwood left by community forests (Neupane 2003).

Deforestation coincided with a rapid increase of remittances to the country. Despite considerable progress on economic development since about 2010, poverty persisted with substantial rural-urban disparity (OPHI 2020). The Nepal Living Standards Survey (NLSS) conducted during 2010–2011 estimates total remittances as 259 billion Nepalese rupee (NPR) (about US$2.61 billion), eight times as much as the total in 1995 in real terms. Of total remittances received by households, overseas remittances had grown from 55% in 1995 to 80% in 2010. The proportion of households that received remittances had also increased from 23% to 56% in the same period. Among remittance-receiving households, about 27%–35% of their income was from remittances. The relatively large share of remittances as a source of rural income in Nepal, along with the rapid growth of overseas remittances to the country, provides an opportunity to study the effect of positive income shocks on deforestation.

This article combines household survey and satellite-based land use data to examine the effects of remittances on deforestation at the ward level—the lowest administrative unit under village development committees (VDCs) or municipalities in Nepal—in the 2001–2010 decade. Land use data for two years, 2001 and 2010, were derived from the U.S. Geological Survey (USGS) Landsat Mapper/Enhanced Thematic Mapper (TM/ETM) scenes with a spatial resolution of 30 m (Guo et al. 2015). The structure of the two-year data allows us to identify the location of deforestation. The land use data are merged with 3,912 household-level observations in 326 wards from NLSS conducted in 2003–2004 (hereafter "NLSS 2003–2004"). The survey contains detailed questions about remittances, household demographics characteristics, housing information, and agricultural activities. Using the combined data set, we relate deforestation to remittances and investigate the possible channels through which remittances may affect smallholder farmers' behavior in land clearing.

This study makes two contributions to the literature. First, the rapid growth of overseas remittances to Nepal creates a source of income variation, which differs from income variation determined within the local economy. Previous empirical research on developing countries associates income growth with forest cover change (e.g., Capistrano and Kiker 1995; Barbier and Burgess 1996). But most evidence addresses association rather than causality because of the limitation of data and methodology (see Angelsen and Kaimowitz 1999; Alix-Garcia et al. 2013). Rates of deforestation can be influenced by multiple factors, such as population growth, road construction, agricultural returns, and forest product prices (Li et al. 2015). These are plausibly confounding variables that influence deforestation and local income, causing a spurious association. By focusing on remittance income, which is relatively independent of the drivers of deforestation in a local economy, our identification of this relationship is less contested by the endogeneity challenge.

Admittedly, remitting behavior occurs mostly within families and is one of the main outcomes of migration that is primarily determined locally. Analytical work on the effect of migration is inherently challenged by the possible endogeneity and selectivity involved in decisions surrounding migration (McKenzie and Sasin 2007; Massey Axinn, and Ghimire 2010), which naturally leads to a concern about potential endogeneity issues with remittances. This concern is supported by the data. Half of the remittance senders surveyed in NLSS 2003–2004 were sons or daughters of recipients, 22% were spouses of recipients, and 11% were fathers or mothers of recipients. Young, working-age men dominated the population of senders (88%), with an average age of 33 years. We seek to tackle this endogeneity issue by instrumenting remittances with exchange rate shocks while controlling for migration. NLSS 2003–2004 suggests that 76% of the remittances Nepalis received were overseas remittances, primarily from nine countries. According to the International Monitory Fund, from 2000 to 2003, currencies of seven countries appreciated against the NPR in a wide range of 3%–48%, whereas currencies of the other two countries depreciated by 10% and 17%, respectively (IMF 2017a). These notable fluctuations in foreign exchange rates, along with a significant diversification of migration destinations emerging in the process of political and economic liberalization (Tiwari and Bhattarai 2011), provide a plausibly exogeneous source of variations in remittances.

Second, this study emphasizes that, to formulate meaningful policy recommendations regarding poverty alleviation and conservation, it is crucial to understand the underlying mechanisms. In addition to examining the remittances-deforestation relationship in Nepal, we explore the household channels of the remittances effect. Most early studies on deforestation center on the identification of the causal relationship between deforestation and its potential drivers, such as wage income and agricultural income (see a comprehensive review by Angelsen and Kaimowitz 1999). But the literature is less concerned with the effect of remittances on forest cover change and is thin with respect to mediation analysis. In recent years, more systematic analyses of the underlying mechanisms have emerged (Alix-Garcia et al. 2013; Oldekop et al. 2018). We examine whether and how remittance income affects agricultural output and usage of input (fertilizer, pesticides, improved seeds, irrigation, and hired labor) from the production side as well as housing improvement and firewood collection from the consumption side. Our analysis therefore attempts to provide a comprehensive picture of the mechanisms underlying the effect of remittance income on deforestation in Nepal.

To put the remittances-deforestation relationship against a larger backdrop, the body of literature on forest transitions is relevant. Places experience forest transitions when a decline in forest cover ceases and a recovery in forest cover begins (Rudel 1998). Rudel et al. (2005) summarize that forest transitions have occurred in two, sometimes overlapping, circumstances. In some places, economic development has created enough nonfarm jobs to pull farmers off their land, thereby inducing the spontaneous regeneration of forests in old fields, referred to as the "economic development path" to forest transitions. In other places, a scarcity of forest products has prompted governments and landowners to plant trees in some fields, referred to as the "forest scarcity path." Moreover, the important role of smallholder farmers is highlighted in forest recovery through such mechanisms as sustainable agricultural intensification, migration, and remittances (e.g., Hecht 2010; Perfecto and Vandermeer 2010). Whether the focus is on deforestation or forest transition, one thing is clear: the implications of migration and remittance economies are a central topic for scholars of immigration policy and transnational studies, yet very little research has focused on the empirical relationship of these monies to the environment (Hecht 2010).

2. Methods and Materials

Relationship between Deforestation, Remittance, and Migration

Deforestation, especially when it is locally confined, closely relates to agricultural expansion. The microeconomics of deforestation has its theoretical root in the von Thünen's (1826) land rent approach, which assumes that land is allocated to the use with the highest rent, and that agricultural-forest frontiers are where agricultural expansion is not profitable anymore. A survey of more than 140 economic models of deforestation finds a broad consensus that higher agricultural prices, lower transportation costs, lower rural wages, and shortage of off-farm employment opportunities are immediate causes of deforestation at the household or village level (Angelsen and Kaimowitz 1999).

Compared with those identified causes, the effect of remittances on deforestation is complex and remains understudied. On one hand, remittances for consumption or production can affect smallholder farmers' decisions about whether to clear forests (Gray and Bilsborrow 2014; López-Feldman and Chávez 2017). On the other hand, remittances are one of the outcomes of out-migration, which confounds with remittances to affect deforestation. Migration flows are considered important drivers of forest transitions, and their effects on reducing deforestation and restoring forest are thought to be influenced by a series of overlapping mechanisms (Hecht and Saatchi 2007; Kull, Ibrahim, and Meredith 2007; Oldekop et al. 2018). In some parts of the world, rural out-migration has contributed to a reduction in deforestation (Rudel 1998; Aide and Grau 2004). Out-migration can reduce population size and subsequently lower demand for agricultural and wood products. When migrants are of working age, migration can decrease agricultural labor force and thus release pressure on forests.

Meanwhile, migration and deforestation are likely confounded. Rural land and labor markets are closely linked. Migration is costly, and smallholder farmers may fund migration through felling trees and selling timber. If the transaction cost associated with the land market is high, households with a limited land endowment may be more likely to migrate, and these households also have incentives to deforest. Migration can be a strategy for escaping poverty, whereas deforestation is often linked to poverty. Moreover, poverty and a household's nonremittance income and assets can influence the level of remittances, depending on how altruistic a sender is and whether the sender is motivated to maintain favor in the line of inheritance (e.g., Ilahi and Jafarey 1999; de la Brière et al. 2002). With a focus on Latin America, Radel et al. (2019) review research on how land change affects migration and how migration affects land systems, particularly forest transitions, to conclude that the relationship is complex and highly context-specific. The earlier expectation that out-migration from rural areas of Latin America would lead to widespread forest regrowth (Aide and Grau 2004) has not been observed in subsequent research (Aide et al. 2013).

The presence of other confounding factors, such as natural or socioeconomic calamities, which concurrently influence all three variables (deforestation, migration, and remittances), further complicates the identification of the causal relationship of remittances and deforestation. Migration and remittances can be a risk-coping strategy to help households deal with, for example, crop failure, price fluctuations, insecurity of land tenancy, and livestock diseases (Katz and Stark 1986; Cox, Eser, and Jimenez 1998; Gray 2009). In most South Asian countries, including Nepal, monsoon flooding–induced crop failure is not uncommon and can affect deforestation. Conflict is another potential confounder. From 1996 through 2006, more than 15,000 people were killed during the Nepalese civil war, an armed conflict between the Communist Party of Nepal and the Government of Nepal. The period 2002–2004 was the most intense, with about two-thirds of civil war deaths (Human Rights Yearbooks, Informal Sector Service Centre). Such a conflict may simultaneously affect forest clearings and the migration behavior of smallholder farmers.

Data

This study relies on remote sensing-based land use data for two years (2001 and 2010) and a nationwide survey of 3,912 households from 326 wards, supplemented with ancillary data sets. Appendix Table A1 presents detailed data description and sources.

The land use data were developed by the International Food Policy Research Institute and the Center for Spatial Information Science and Systems, George Mason University, using USGS TM/ETM scenes (Guo et al. 2015). The team acquired 14 scenes of LandSat satellite series from the USGS's EarthExplore repository for 2001 and 2010 and used ISOData clustering and the Support Vector Machine–supervised classification algorithm to develop the land use data at the 30 m resolution. The data identify eight main land use classes in Nepal. The overall accuracy of land use classification is 83%, validated with ground-truth data collected by local collaborators from Nepal. We focus on forestland, including broadleaf forests and needle forests. We define "area deforested" as the area of land that was covered by forests in 2001 but was cleared for other uses by 2010. Deforestation is measured by the rate of deforestation over the period 2001–2010 (i.e., the total area deforested divided by the total forest cover in 2001 in each ward).

The primary source of socioeconomic data is the second round of NLSS, a national integrated household survey conducted by the Central Bureau of Statistics (CBS) of Nepal from April 2003 to April 2004. The NLSS collected detailed information on the different aspects of household characteristics and welfare, including ethnicity, income, housing, education, and agricultural output and input during the past 12 months. To date, CBS has undertaken three rounds of NLSS in 1995–1996, 2003–2004, and 2010–2011; the second round falls in the time window of this study. Sample size concern prevented us from using multiple rounds of NLSS.[1]

Following the methodology of the Living Standards Measurement Survey developed by the World Bank, CBS used a two-stage stratified sampling scheme to select a nationally representative sample for NLSS 2003–2004. Specifically, the country was partitioned into six strata according to ecological zones and rural/urban classification. In each stratum, primary sampling units (PSUs) were selected by using probability-proportional-to-size sampling, with the size measured by the number of households based on the 2001 population census of Nepal. Subsequently, 12 households were randomly selected in each PSU. The PSUs are mostly administrative wards of VDCs or municipalities.[2] Our study restricts analysis to PSUs (hereafter called wards) at least partly covered by forests as of 2001. This restriction, along with missing data, yields a usable sample of 3,889 households from 281 wards for the empirical analysis. The probability-proportional-to-size sampling implies that a ward with a larger number of households is more likely to be chosen. We examine the representativeness of the NLSS sample for the rate of deforestation in a ward by comparing the empirical distribution of deforestation and the summary statistics between the NLSS sample and the statistical population of all wards in the country (see Appendix A1 for details on the comparison). We conclude that the stratified NLSS 2003–2004 sample is representative of the rate of deforestation at the ward level.

We also use several ancillary data sets, including long-term rainfall and temperature data from the closest weather stations, conflict-related death toll during the most intense years of the Nepal civil war, the presence of CFP, and exchange rates. Time-series weather station data were collected from 277 national stations to calculate the median and the interquartile range (IQR), standardized by the median, of annual precipitation in 1990–2010. We use these variables to proxy for the risks of flood-induced crop failure. The Informal Sector Service Centre, a leading human rights organization in Nepal, reports the number of people killed in each district from 1996 through 2006. We use the conflict-related death toll during 2002–2004—the most intense period during the civil war—to measure the intensity of the conflict.

Information on CFP was drawn from an up-to-date database of forest user group (FUG) registrations compiled by the Community Forestry Division, Department of Forest of Nepal. The database has detailed records, starting in 1988, of each FUG, including the village development committees and wards to which the group belongs, date of implementation, and involved area. Finally, we retrieved data on nominal exchange rates for selected currencies for 2000–2003 from the IMF (2017a). We use the exchange rates together with corresponding GDP deflators (IMF 2017b) to calculate real exchange rates for the reported currencies in which remittances were made.

[1] E.g., if we combined the last two rounds of NLSS, the panel sample of NLSS 2010/11 consists of 100 wards visited by NLSS 2003–2004. Fifty of them were taken from the cross-sectional component of NLSS 2003–2004; the remaining 50 were taken from the panel component of NLSS 2003–2004, which were visited by NLSS 1995–1996. The cross-sectional and the panel components were sampled separately and thus cannot be simply combined. This would reduce the usable sample from 326 wards to a maximum of 50.

[2] In rare cases (e.g., large urban wards in metropolitan areas), the segments of the wards were selected as PSUs. This segmentation is not a concern for our study because most of the segments were removed from the sample owing to their little forest cover. Thus, it is safely assumed that PSU is equivalent to ward based on our discussion with the CBS officers.

Empirical Strategy

We fit the cross-sectional data to the following equation to estimate the effect of remittances on deforestation:

$$y_i = \beta_0 + R_i\beta_1 + M_i\beta_2 + \mathbf{W}_i\boldsymbol{\beta}_3 + \mathbf{X}_i\boldsymbol{\beta}_4 + \varepsilon_i, \quad [1]$$

where y_i represents the rate of deforestation in ward i over the period 2001–2010; R_i represents remittances received by all members of a household during the 12 months prior to the survey interview, averaged across all sampled households in ward i; M_i represents estimated extent of migration averaged across all sampled households in a ward; $\mathbf{W}_i$ is a vector of ward-level factors or household characteristics averaged at the ward level that plausibly confound with remittances or migration to affect deforestation; $\mathbf{X}_i$ is a vector of other control variables; and ε_i is an error term. Table 1 reports the summary statistics of all the variables used.

The vector $\mathbf{W}_i$ includes long-term median annual precipitation, long-term IQR of annual precipitation, conflict-related death toll, per capita land endowment (excluding people younger than 15 years), CFP, caste groups (high/Dalit/Janajati), share of male headship, age of household head, and education of household head in years. The vector $\mathbf{X}_i$ includes log of forest area in 2001 and ecological zone dummies. Here we only consider variables that may affect deforestation without causing serious endogeneity issues. Variables such as households' nonremittance income and community population may also impose pressure on forest clearing, but such variables are problematic because they could be the result of deforestation or highly correlated unobserved factors in the error term.

Historically, flooding has been a more common stressor for Nepali farmers than drought due to the heavy and erratic rainfall in the monsoon period. The long-term median and the IQR of annual precipitation (1990–2010) observed from the closest weather station from ward i were used to proxy for risks in crop failure attributed to rainfall. We used the conflict-related death toll to measure conflict intensity and the per capita land endowment to measure the degree of land scarcity. CFP is a binary variable indicating in any given ward whether at least one FUG registered for CFP before 2001. Community forestry, introduced by the government in the early 1980s and reinforced by the 1993 Forest Act, has handed over all the accessible national forests to the local people for their management and use (Kanel 2012), which can potentially influence deforestation in a community. We exclude FUGs registered after 2001 because those registrations may be the result of deforestation that occurred during our study period.

Variables associated with household attributes capture the role of ethnic and demographic characteristics, which may affect family wealth, asset accumulation, and occupation. We used the shares of high caste, Janajati, and Dalit populations in a ward to measure poverty, a potential driver of deforestation, migration, and remittances. Bennett, Dahal, and Govindasamy (2008) found significant caste disparities in poverty and human development outcomes. Characterized by its hierarchical structure and hereditary basis, the Nepalese caste system stratified social classes and life chances of Nepalis over hundreds of years. NLSS 2003–2004 records 80 ethnic groups from seven classes (NCBS 2003; Bennett, Dahal, and Govindasamy 2008). Among them, high caste (primarily Chhetri, Bahun, and Thakuri, 31.3%), Janajati (indigenous people, 30.7%), Dalit/low caste (untouchable, 11.7%), and Newar (10.2%) dominate the NLSS sample. We further grouped high caste and Newar together (hereafter, high caste). Composed of habitants of the Kathmandu Valley, Newar is an upper-ranking caste where people dominate the civil service and judiciary.

Issues with Identification

Of primary interest is the remittances variable R_i. Motivations to remit and the determinants of amount remitted are complex. One may expect that remittances are endogenous if variations in remittances primarily result from variations in out-migration, and there are omitted variables affecting deforestation and out-migration simultaneously. We adopt the instrumental variable (IV) approach to

Table 1
Summary Statistics of Sample Ward Characteristics

Variable	Full Sample		Sample with Wards Receiving Remittances	
	Mean	Standard Deviation	Mean	Standard Deviation
Ward area (ha)	452.0	1169.5	461.6	1193.5
% ward in agriculture in 2001	51.4	30.0	51.6	29.6
% ward in forests in 2001	45.1	30.3	45.4	30.0
% deforestation during 2001–2010	36.4	30.5	35.9	30.3
Average remittances received by household (100,000 NPR)	0.094	0.111	0.098	0.112
Average number of family migrants	0.414	0.265	0.432	0.256
Average number of family absentees	0.095	0.074	0.096	0.073
Median annual precipitation (1,000 mm)	1.898	0.724	1.908	0.725
Interquartile range of annual precipitation (1,000 mm)	0.261	0.100	0.260	0.096
District average conflict-related death toll during 2002–2004	144	95	145	95
Share of high-caste households (including Newar)	0.412	0.332	0.417	0.329
Share of Dalits and low-caste households	0.130	0.161	0.132	0.162
Share of Janajati households	0.344	0.315	0.339	0.312
Average age of household heads (years)	46.0	4.90	46.1	4.93
Share of male headship	0.794	0.151	0.788	0.151
Average formal education of household heads (years)	2.45	1.63	2.45	1.62
Per capita land endowment (ha)	0.201	0.114	0.199	0.111
Is the ward involved community forestry program (1 if yes)?	0.287	0.453	0.299	0.459
Exchange rate shocks of overseas remittances in a ward (%)	2.22	2.40	2.31	2.41
Exchange rate shocks of overseas remittances in a district (%)	0.889	0.703	0.902	0.707
Share of migrants to developed countries	0.089	0.167	0.093	0.170
Observations	281		266	

Note: Stratum weights are applied to the calculation.

address this endogeneity concern with two sequential specifications.[3]

We start with a parsimonious IV model, excluding migration (M_i) and all explanatory variables ($\mathbf{W}_i$) that are possibly correlated with migration. The empirical model is specified as

$$y_i = \beta_0 + R_i\beta_1 + \mathbf{X}_i\boldsymbol{\beta}_4 + \epsilon_i \quad [2]$$

and

$$R_i = \alpha_0 + Z_i\alpha_1 + \mathbf{X}_i\boldsymbol{\alpha}_4 + \xi_i, \quad [3]$$

where Z_i represents exchange rate shocks—the excluded instrument for remittances; $\mathbf{X}_i$ is defined the same way as in equation [1], serving as included instruments; and ϵ_i and ξ_i are error terms.

According to NLSS 2003–2004, half the remittances senders were overseas migrant workers mostly dispersed across several Asian countries (Table 2). India was the largest single destination, with 32.1% of the total migrants. Saudi Arabia came in second with 5.5%, followed by Malaysia and Qatar, with 3.5% and 2.5%, respectively. Other countries (or regions), including the United Arab Emirates, the United States, the United Kingdom, Hong Kong, Japan, and unreported countries, accounted for 5.7% of the total. Between 2000 and 2003, the currencies of most destination countries appreciated against the NPR. For example, the currencies of the main Gulf countries (Saudi Arabia, the United Arab Emirates, and Qatar) rose 14.1%–47.8% in value against the NPR, and those of India and Malaysia rose by 2.9% and 10.8%, respectively. Appreciation of foreign currencies was a positive income shock for an overseas migrant's origin family in Nepal—the greater the appreciation

[3] Statistical matching techniques, such as the propensity scoring method, are not appropriate here. Of 281 sampled wards, households from 266 wards (treatment group) received remittances, leading to a very small control group of only 15 wards. The significant difference in the sample size between the treatment and the control groups makes it difficult to pair the treated and control units.

Table 2
Location of Migrants from Sample Households

Location	Number of Migrants	% Total	Exchange Rate Shock, 2000–2003 (%)
Nepal	760	50.8	—
India	480	32.1	2.9
Saudi Arabia	82	5.5	14.5
Malaysia	52	3.5	10.8
Qatar	37	2.5	47.6
United Arab Emirates	14	0.9	14.1
United States	12	0.8	5.0
United Kingdom	12	0.8	5.5
Hong Kong, China	10	0.7	−16.8
Japan	6	0.4	−9.9
Other countries	32	2.1	n/a.
Total	1,497	100.0	

Source: Authors' calculations using data from the Nepal Living Standards Survey (2003–2004) and the IMF rates database. Exchange rate shock is the % change in Nepalese rupees per currency unit between 2000 and 2003.

of the migrant's currency against the NPR, the larger the amount of remittances the origin family received.

To construct the exchange rate shocks variable, we follow Yang's (2008) approach by first calculating the exchange rate change (*ERCH*) in percentage for each currency j between 1999–2000 and 2002–2003:

$$ERCH_j = \left(\frac{\substack{\textit{Average currency exchange rate} \\ \textit{from Jan.}2002 \textit{ to Dec.}2003}}{\substack{\textit{Average currency exchange rate} \\ \textit{from Jan.}1999 \textit{ to Dec.}2000}} - 1 \right) \times 100\%,$$

where the exchange rate is measured in NPR per unit of currency j evaluated in 2000. We allow the starting period one year earlier than our study period to capture the time-lag effect of the exchange rate effect on remittance sending. The exchange rate shocks variable is then constructed by averaging $ERCH_j$ across all currencies for each ward using a weighting factor computed as follows: the number of migrants from a ward to each country or region (including Nepal) divided by the total number of migrants from the ward.[4] We discuss the validity of exchange rate shocks as an instrument for the causal effect of remittances on deforestation based on the five assumptions proposed by Angrist, Imbens, and Rubin (1996); these assumptions constitute sufficient conditions for identifying a meaningful causal inference.

Assumption 1: Stable Unit Treatment Value Assumption

Generally, deforestation in each ward is unrelated to the remittances received by households in other wards. One exception is that if a domestic migrant moves specifically to engage in land-clearing activities, the rate of deforestation in the destination ward will increase. Since the migrant may send earnings back home, the assumption of independence between deforestation in the destination ward and remittances to the origin ward can be violated. Yet violating the stable unit treatment value assumption (SUTVA) is not a major concern in our study because 48% of domestic migrants moved to urban areas and 78% worked in nonagricultural sectors, leaving only 10% of migrants engaged in agricultural activities in rural areas of Nepal. We empirically assessed this assumption and found no evidence for violation of SUTVA (Appendix Table A5).

Assumption 2: Random Assignment of Exchange Rate Shocks

The exchange rate approximately follows a random walk in the conventional literature of macroeconomics (e.g., Meese and Rogoff 1983; Moosa and Burns 2014). Previous assessments of nominal exchange rate determination and forecasting changes in exchange rates established the stylized fact that it is extremely difficult to beat a random walk on a consistent basis (Chinn 2003).

[4] A standard practice in the literature to abate the potential endogeneity of a weight variable is to construct it using the number of migrants in the previous period (e.g., extracting relevant variables from the first round of NLSS 1995–1996 in the case of Nepal). But adopting this strategy would cause new problems because (1) the structure of remittance source had changed significantly from 1995–1996 to 2003–2004 (e.g., the total share of remittances within Nepal and from India decreased from 77% in 1995–1996 to 47% in 2003–2004) and (2) only 100 wards from NLSS 1995–1996 were revisited by NLSS 2003–2004. Using the lagged weight variable would greatly reduce our sample size.

Assumption 3: Nonzero Average Causal Effect of Exchange Rate Shocks on Remittances

This assumption requires that exchange rate shocks have strong explanatory power in explaining the variations of remittances (i.e., "strong" instrument), which is tested and confirmed in Section 3.

Assumption 4: Monotonicity

This assumption implies that remittances must be a nondecreasing function of exchange rate shocks, which is likely to hold in the context of this study. Appreciation of foreign currencies in overseas migrants' destination countries will always increase the amount of remittances in NPR the origin family received, ceteris paribus. Even though migrants may reduce the remittances (in foreign currency) they had planned to send due to currency appreciation, the remittances in NPR received by their origin family should not be less than the amount when there is no currency appreciation (i.e., migrants have no incentive to send much less money under currency appreciation). Similar logic holds for the case of foreign currency depreciation in overseas migrants' destination country.

Assumption 5: Exclusion Restriction

Exclusion restriction requires that the effect of exchange rate shocks on deforestation must be strictly via the effect of exchange rate shocks on remittances. It follows that by holding remittances (and other covariates) fixed, the rate of deforestation in any particular ward would remain constant regardless of how exchange rates fluctuated. Because the exclusion restriction concerns counterfactuals that are never observed and is not directly verifiable from the data at hand, we assessed the possibility of violation of this assumption by investigating two potential channels: (1) the effect of exchange rate shocks on forestry and agricultural production and trade and (2) the effect of exchange rate shocks on migration.

There is no evidence that appreciation of foreign currencies against the NPR changed production of the major wood products—round wood and wood fuel—in Nepal. The annual production of the two products was quite stable between 2001 and 2010, in the range of 13.8–14.0 million m^3 and 12.5–12.8 million m^3, respectively (FAO 1997). The annual import and export quantities of these products are negligible, accounting for less than 0.0095% of production. Nor is there evidence that appreciation of foreign currencies affected the country's international trade of agricultural products. Between 2001 and 2010, the annual import and export quantities of cereal (primary crops) erratically fluctuated in the range of 30,000–294,000 metric tons and 2,000–54,000 metric tons, respectively (FAO 1997). The annual cereal net import accounts for only 0.33%–3.95% of production over this period.

As for the migration channel: the exclusive restriction implies that exchange rate shocks change the amount of remittances but not the number of migrants. To verify this implication, we estimated the ward-level Pearson correlation coefficient between exchange rate shocks and migration, the latter being measured by the total number of migrants from a ward and the ratio of migrant numbers over household size. The two correlation estimates are close to zero and statistically insignificant (p-values = 0.22 and 0.72, respectively; see the upper panel of Appendix Table A3). This result is in sharp contrast to the Pearson correlation coefficient between exchange rate shocks and remittances, which is estimated to be 0.455 at the 1% level of significance.

A further concern arising from the exclusive restriction assumption with respect to the migration channel was that exchange rate shocks may change the incentives to migrate after 2003. To preclude this possibility, we exploited the panel component of NLSS 2003–2004 and NLSS 2010–2011 to calculate changes in the two migration measures at the household level. The panel component contains 616 households in total. We calculated exchange rate shocks using the number of migrants from a household surveyed in NLSS 2010–2011 as the weighting factor. As anticipated, there is no significant correlation between exchange rate shocks and migration change, and their Pearson correlation coefficients are almost zero (see the lower panel of Appendix Table A3). This result is robust to the alternative weighting factor of the number of migrants from a household surveyed in NLSS 2003–2004.

Another underlying assumption is that the migration destination–based weighting factor is orthogonal to unobserved ward-specific determinants of deforestation. The rate of deforestation can be correlated with migration. But it is possible that this rate is uncorrelated with the selection of migration destination under certain circumstances. Whether to migrate and where to migrate are not the same decisions, though they are related. Historically, the primary reason for migration out of Nepal has been inadequate year-round employment in villages (Tiwari and Bhattarai 2011). Although factors that drive the decisions on migration and deforestation are not mutually exclusive, selection of migration destination is more likely to be influenced by migrants' and their origin families' social networks as well as by the ethnicity/language/religion proximity of the destination to achieve economic success (Montgomery 1991; Massey et al. 1993; Munshi 2003). To examine whether unobserved heterogeneity associated with the selection of migration destination preexists across wards, we estimated the ward-level Pearson correlation coefficients between the share of migrants to each country (i.e., migration destination–based weighting factor) and area in forest, area deforested, and the rate of deforestation, respectively. The correlation estimates for all countries, except Malaysia, are close to zero and statistically insignificant (see Appendix Table A4, panel A, columns [1]–[3]). We further calculated the Pearson correlation coefficient between the share of migrants to each country and the total number of migrants in each ward. Only the estimate for domestic migration is significantly negative at the 10% level, while the estimates for other countries are statistically insignificant (see Appendix Table A4, panel A, column [4]). This result confirms that whether to migrate and where to migrate are different decisions.

Therefore, we conclude that the exclusion restriction assumption of exchange rate shocks is unlikely to be violated in this study. There is no evidence that exchange rate shocks affect the annual production of major wood and agricultural products or the extent of migration in Nepal, and there is no evidence that selection of migration destination is correlated with deforestation. Among the five assumptions, monotonicity and exclusion restriction form the core of the IV approach. The higher the correlation between exchange rate shocks and remittances (i.e., the "stronger" the instrument), the smaller the bias from violations of the exclusion restriction and monotonicity assumptions (Angrist, Imbens, and Rubin 1996).

The proceeding discussion suggests that exchange rate shocks are plausibly a valid instrument for the causal effect of remittances on deforestation; we extend the parsimonious IV model to a more comprehensive one by instrumenting both remittances and migration in equation [1]. The remittances and migration equations are respectively specified as

$$R_i = \alpha_0 + Z_i\alpha_1 + S_i\alpha_2 + \mathbf{W}_i\boldsymbol{\alpha}_3 + \mathbf{X}_i\boldsymbol{\alpha}_4 + u_i \qquad [4]$$

and

$$M_i = \alpha_0 + Z_i\gamma_1 + S_i\gamma_2 + \mathbf{W}_i\boldsymbol{\gamma}_3 + \mathbf{X}_i\boldsymbol{\gamma}_4 + \upsilon_i, \qquad [5]$$

where S_i represents the proportion of migrants to developed countries, an extra IV in addition to exchange rate shocks Z_i; $\mathbf{W}_i$, and $\mathbf{X}_i$ are defined the same way as in equation [1]; and u_i and υ_i are error terms.

We calculated the proportion of migrants to developed countries based on the location of migrants reported in NLSS 2003–2004, which indicates that 23% of overseas migrants moved to developed countries. As part of its liberalization reforms, Nepal gave freer rein to international migration. Beginning in the mid-1990s, the Government of Nepal removed restrictions on obtaining passports and visas to seek overseas work. It also entered a series of labor agreements with several fast-growing countries in East and Southeast Asia, such as South Korea and Malaysia, and in the Gulf region, such as Saudi Arabia, the United Arab Emirates, and Qatar (Tiwari and Bhattarai 2011). These reforms opened new destinations that were previously inaccessible to Nepali migrants. The Pearson correlation coefficient estimates reported in Appendix Table A4, panel A, supports the assumption that migration destination is exogenous to deforestation.

Thus far, we have discussed the validity of exchange rate shocks and proportion of migrants to developed countries from the perspective of institutional knowledge about remittances and migration. An additional instrument is preferred to further assess the exogeneity of these two IVs. But finding another good instrument that is uncorrelated with migration is difficult. In the absence of such IV candidates, we constructed a variant of exchange rate shocks by replacing the ward-level weighting factor with the district-level weighting factor extracted from NLSS 1995–1996 (i.e., the number of migrants from a district to a given country or region divided by the total number of migrants from that district). The district level is the most disaggregate level that allows us to combine the two-rounds survey (see n. 1 for more details).

3. Results

To identify the effect of remittances on deforestation, we first focus on equation [1]. Since the rate of deforestation is bounded between zero and unity, we estimate equation [1] with fractional logistic regressions and use ordinary least squares (OLS) regression to examine whether the estimated remittance effect is sensitive to the nonlinear data nature. Fractional logit is chosen because it is relatively robust to the probability distribution of fractional response variables among other nonlinear regressions (Papke and Wooldridge 1996). We use a two-stage logistic regression approach to separately estimate equations [2] and [3] and equations [1], [4], and [5] to address the potential endogeneity issue. The advantage of the two-stage approach over the maximum likelihood–type method is that the former generally produces estimates that are not sensitive to model specification. This robustness is critical to the estimation of a deforestation model as deforestation may be driven by many forces.

Do Remittances Affect Deforestation?

Table 3 presents the results from the estimation of equation [1]. Column (1) corresponds to the most parsimonious version of the ordinary fractional logistic model, which only includes remittances and the two control variables defined in **X**. Column (2) reports the results from adding the migration variable. The specification of column (3) adds another 11 confounding variables defined in **W**; most variables are exogenous to deforestation, while migration is controlled. The specification of column (4) excludes the migration variable from column (3). Columns (5) and (6) present the results from logistic regressions where remittances are specified as a reduced form of migration. The last column reports the estimation results from OLS regression on deforestation.

The results in Table 3 can be summarized into several points. The rate of deforestation decreases with remittances at the significance level of 1%–5% across all logistic specifications, implying that the estimated remittance effect is robust to adding additional confounding variables. Quantitatively, the remittance effect obtained from the parsimonious equation (column [1]) is smaller in magnitude than that from the models that control for migration and other covariates (columns [2] and [3]). Because the effects of remittances and migration on deforestation are mutually nonexclusive and the estimated remittance effect in column (1) is more inclusive, it can be plausibly argued that the negative effect of remittances on deforestation reported in column (3) is partly offset by a hypothetical positive effect of migration and the covariates **W**, thereby resulting in a smaller net effect on deforestation as shown in column (1). As for the marginal effect, on average, an additional 1,000 NPR increase in household annual remittance income reduces the rate of deforestation by 0.299–0.450 percentage points in a ward and the associated elasticity ranges between –0.077 and –0.117, all else being equal.

There is no significant correlation between deforestation and migration. But one cannot simply attribute this statistical insignificance to the absence of causal relationship between the two variables. Rather, it is likely that the presence of extraneous forces counteracts the pressure-reducing effect of migration on deforestation. As discussed in Section 2, migration can be a risk-abatement strategy for households, and rural households may accelerate deforestation when they face risk

Table 3
Estimation on Deforestation without Instrumental Variables

	Fractional Logit						Linear
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Remittances	−1.304***	−1.445**	−1.975***	−1.666***			−0.410*
	(0.392)	(0.715)	(0.639)	(0.355)			(0.228)
Migration		0.110	0.330		−0.200	−0.034	0.070
		(0.365)	(0.294)		(0.249)	(0.170)	(0.099)
Median annual precipitation			−0.024	−0.048		−0.066	−0.006
			(0.098)	(0.116)		(0.108)	(0.024)
IQR of annual precipitation			0.701	0.720		0.483	0.130
			(0.840)	(0.791)		(0.767)	(0.202)
Conflict-related death toll			−0.480	−0.447		−0.251	−0.106
			(1.422)	(1.453)		(1.381)	(0.219)
Share of high-caste members			0.971***	0.967***		0.935***	0.203
			(0.206)	(0.218)		(0.224)	(0.127)
Share of Dalit members			−0.049	−0.016		−0.103	−0.004
			(0.323)	(0.340)		(0.339)	(0.151)
Share of Janajati members			0.723***	0.672***		0.613***	0.158
			(0.218)	(0.163)		(0.159)	(0.122)
Age of head			−0.032**	−0.028*		−0.035**	−0.007*
			(0.015)	(0.016)		(0.014)	(0.004)
Share of male headship			−0.131	−0.343		0.161	−0.021
			(0.477)	(0.649)		(0.461)	(0.133)
Years of formal education of head			0.037	0.028		0.004	0.008
			(0.034)	(0.028)		(0.030)	(0.013)
Per capita land endowment			−0.170	−0.160		−0.118	−0.040
			(1.553)	(1.558)		(1.653)	(0.155)
CFP (1 if involved)			−0.152	−0.157		−0.157	−0.033
			(0.132)	(0.134)		(0.131)	(0.035)
Ln (area in forest), 2001	−0.224***	−0.224***	−0.265***	−0.261***	−0.223***	−0.264***	−0.058***
	(0.075)	(0.077)	(0.074)	(0.071)	(0.069)	(0.067)	(0.011)
Residual log pseudo-likelihood	−510.54	−510.93	−510.94	−510.90	−509.99	−510.77	
R-squared							0.272
Ecological zone	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Marginal effect of remittances	−0.299***	−0.331**	−0.450***	−0.380***			
	(0.089)	(0.162)	(0.144)	(0.080)			

Note: The sample includes 281 wards. Normalized stratum weights are applied to the estimation of all the models. Standard errors are in parentheses. The marginal effect is evaluated at the sample means, with the standard error being calculated using the delta method.
*, **, and *** Significance at the 10%, 5%, and 1% levels, respectively.

of financial insecurity. Other factors, such as poverty, landholding, or fundraising for migration, can also influence migration and deforestation in the same direction. Further investigation of how these effects act and interact in households' decision-making of migration is beyond the scope of this study. Nonetheless, migration affects deforestation through multiple channels, making its net effect statistically insignificant in the context of this study.

A comparison of migration estimates between the regressions that control for remittances (columns [2] and [3]) and the reduced-form regressions (columns [5] and [6]) provides insight into the complex migration-remittance-deforestation interlinkage from a different perspective. Purging migration effect of the remittance component substantially increases the coefficient estimate of migration. This comparison reconfirms the hypothetical negative effect of remittances on deforestation. Finally, inspecting column (7) and the other columns provides a comparison of the OLS estimate with the estimated marginal effects in logistic models. The negative effect of remittances on deforestation obtained from the OLS regression is slightly smaller in magnitude and weaker in statistical significance than its logistic counterpart (–0.410 at the 10% level in column [7] vs. –0.450 at the 1% level in column [3]).

Is the Potential Endogeneity a Cause for Concern?

To examine whether the potential endogeneity of remittance causes for concern to identify its causal effect on deforestation, we used the IV approach to reestimate the deforestation equation and report the estimation results in Table 4. Columns (1a)–(2b) present the point estimates from the parsimonious model (i.e., equations [2] and [3]) where the specification is exclusive of migration and the plausible confounding variables. Columns (3a)–(4c) present the estimation results from the comprehensive model (i.e., equations [1], [4], and [5]) in which migration is explicitly treated as an endogenous variable in addition to remittances while the confounding variables are controlled.

Before turning to the variable of interest, it is useful to discuss the validity of the IVs used. Remittances expectedly increase with the ward- and district-level exchange rate shocks between 2000 and 2003 and with the proportion of migrants to developed countries at the significance level of 5% or better. These three IVs are strong instruments for remittances; the F-test of significance of instrument in the first-stage regression shows a value in the range of 39.3–110.6 (columns [1a], [2a], [3a], and [4a]); this is much higher than the level of 10 typically recommended for rejecting weak instruments (Staiger and Stock 1997). In contrast, these instruments are weakly correlated with migration, with a joint F-statistic of 3.04 (column [3]b) and 2.19 (column [4b]), respectively. Among the three instruments, only the proportion of migrants to developed countries is significant at the 5%–10% level in the first-stage migration equation, whereas the other two instruments constructed from exchange rate shocks are statistically insignificant. Although the associated point estimates must be interpreted with caution, these statistical tests reinforce the validity of exchange rate shocks to instrument for remittances in the parsimonious model (i.e., there is no correlation between exchange rate shocks and omitted migration effect).

Across the specifications, a test of overidentifying restrictions supports the instrument exogeneity assumption. The Wu-Hausman endogeneity test fails to reject the null hypothesis that remittances and migration are uncorrelated with the error term in the deforestation equation in the parsimonious and the comprehensive models (the associated p-value is above the level of 0.84). Admittedly, the Wu-Hausman test is not always informative about endogeneity, depending on whether the model is properly specified and the IVs are valid. Because it is not uncommon to fail to reject the null of the Wu-Hausman test even when the IVs are good (in our case, exchange rate shocks are plausibly a valid instrument for remittances), we refrain from claiming exogeneity of remittances and report results from the IV models.

Turning to the remittance variable, its point estimates are robust to adding an additional instrument. These estimates are significantly negative with greater p-values than those from the ordinary logistic regressions presented in Table 3. The point estimates obtained from the parsimonious IV models are smaller in magnitude than their ordinary counterpart presented in Table 3, column (1), and therefore more conservative. In contrast, the point estimates obtained from the comprehensive IV models are nearly identical to their ordinary counterpart reported in Table 3, column (3). This result suggests that controlling for migration and the confounding factors **W** helps purge the likely sources of bias and allows us to focus on the effect of remittances alone. The specification presented in Table 4, columns (3a)–(3c) (i.e., the comprehensive IV model) is thus the preferred model. In the present study, we prefer a just-identified model to an overidentified one where the number of instruments exceeds the number of endogenous variables. The intent in estimating an overidentified model is to examine the exogeneity of instruments. Increasing the number of instruments does not significantly improve the prediction accuracy of remittances and migration but is more likely to be subject to invalid instruments critiques.

Table 4

Estimated Remittances Effect on Deforestation Using Instrumental Variable Approach

	Parsimonious Two-Stage Fractional Logit				Comprehensive Two-Stage Fractional Logit					
	Remittances (1a)	Deforestation (1b)	Remittances (2a)	Deforestation (2b)	Remittances (3a)	Migration (3b)	Deforestation (3c)	Remittances (4a)	Migration (4b)	Deforestation (4c)
Panel A: Parameter Estimates										
Remittances		–1.003*		–0.980*			–1.906**			–1.927**
		(0.603)		(0.582)			(0.819)			(0.811)
Migration							0.076			0.064
							(0.726)			(0.724)
Exchange rate shocks (ward level)	0.025***		0.024***		0.012***	–0.003		0.011***	–0.004	
	(0.002)		(0.002)		(0.003)	(0.008)		(0.003)	(0.009)	
Exchange rate shocks (district level)			0.020**					0.017**	0.015	
			(0.008)					(0.008)	(0.020)	
Developed countries					0.171***	0.232*		0.193***	0.250**	
					(0.047)	(0.123)		(0.048)	(0.126)	
Control variables W	No	No	No	No	Yes	Yes	Yes	Yes	Yes	Yes
Control variables X	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Marginal effect of remittances		–0.230*		–0.225*			–0.435**			–0.440**
		(0.138)		(0.134)			(0.187)			(0.186)
Panel B: Test and Fit Statistics										
Instrument *F*-test	110.6***		59.3***		55.6***	3.04**		39.3***	2.19*	
(*p*-value)	(<0.0001)		(<0.0001)		(<0.0001)	(0.050)		(<0.0001)	(0.089)	
Wu-Hausman test		0.030		0.040			0.337			0.498
(*p*-value)		(0.859)		(0.840)			(0.947)			(0.864)
Overidentification test				0.110						1.550
(*p*-value)				(0.740)						(0.213)
R-squared	0.293		0.308		0.510	0.408		0.519	0.401	

Note: The sample includes 281 wards. Normalized household weights are applied to the estimation of all the models. Standard errors are in parentheses, except the three test statistics reported in panel B where the associated *p*-value is in parentheses. The marginal effect is evaluated at the sample means, with the standard error calculated using the delta method.

** and *** Significance at the 5% and 1% levels, respectively.

Robustness Checks

In addition to the identification strategy already discussed, we probed the robustness of the estimated remittance effect in several other ways but found little evidence that undermines the main conclusion. Appendix Tables A5–A7 report the results of several robustness checks.

One possible concern over this causal inference is SUTVA with respect to domestic migration. To assess how important the problem might be, we reestimated equation [1] by controlling for the share of migrants to rural areas while working in agricultural sectors. The estimation results presented in Appendix Table A5 are qualitatively and quantitively similar to their unconditional counterparts reported in Tables 3 and 4, indicating that the casual inference is robust to SUTVA with respect to domestic migrants.

Another potential source of bias arises from the way migration is determined. In addition to long-term migrants, we included the number of adults who spend at least one month away from home (i.e., household absentees) to jointly measure the extent of migration.[5] If those absentees are not temporarily away from home, excluding household absentees from the analysis may compress the size of out-migration and subsequently overestimate the effect of migration on deforestation. To examine whether the negative effect of remittances on deforestation is sensitive to the exclusion of household absentees, we included absentees in the calculation of migration and reestimated equation [1] using both the ordinary and the two-stage fractional logistic regressions. Results indicate that the negative effect of remittances on deforestation persists (Appendix Table A6), with slightly larger magnitudes than those reported in Tables 3 and 4. Again, there is no significant correlation between migration and exchange rate shocks, regardless of what factors are used to weight the exchange rate change of each currency.

[5]The NLSS reports migration and household absentees in two distinct sections. Double counting is not a concern. Our examination of the migrants' characteristics (e.g., gender, age, location) indicates that rarely does a migrant send remittances to multiple household members multiple times during the 12 months before the survey interview.

Another round of robustness check involves the elimination of wards where there were no migrants. Of the 3,889 households, 1,202 received remittances, leading to a reduced sample of 266 wards with migrants. We reestimated equation [1] and equations [1], [4], and [5] on this reduced sample. Appendix Table A7 presents the primary point estimates. The sample reduction slightly lowers the magnitude of estimated remittances effect, but it does not impair the basic conclusion drawn from the full sample analyses.

Exploring Household Channels of Effects

We explore the possible channels underlying the mitigating effect of remittances on deforestation from the perspectives of households' productive and consumptive activities. Using household-level data from NLSS 2003–2004, we examined whether remittances may have reduced pressure on forestland by changing agricultural output and input use (fertilizers and pesticides, improved seeds, irrigation, and hired labor), and whether remittances may have reduced timber and fuelwood demands through changing materials for building house and cooking. These response variables are regressed separately on remittances. Two-stage Tobit regression was applied to the estimation of models where response variables are bounded below by a significant number of zero-valued observations, and two-stage probit regression was applied to the estimation of models with binary response variables by instrumenting remittances and migration with the household-level exchange rate shocks and proportion of migrants to developed countries (estimation results without IVs are reported in Appendix Table A9). We assume independence across wards, allowing the households in each ward to be correlated. With a large number of clusters and relatively small cluster sizes, the estimates are robust to arbitrary within-cluster correlation, either in linear or nonlinear models (Wooldridge 2002).

Table 5 presents the primary point estimates on the productive side. Columns (1) and (2) present the results from the first-stage

Table 5

Estimated Remittances Effects on Household Farming Activities

	First Stage		Second Stage					
			Linear		Tobit			Poisson
	Remittances (1)	Migration (2)	Ln (Yield) (3)	Ln (Total Outputs) (4)	Fertilizer and Pesticides (5)	Irrigation/Water Course Maintenance (6)	Expenditure on Labor Hiring (7)	Adoption of Improved Seeds (8)
Panel A: Parameter Estimates								
Remittances			−0.221	0.282	1.382	−0.927	10.856**	0.639
			(0.236)	(0.322)	(2.183)	(1.032)	(5.046)	(4.200)
Migration			0.094	−0.127	−1.045	0.696	−5.193	−0.493
			(0.194)	(0.249)	(1.709)	(0.782)	(3.883)	(3.030)
Exchange rate shocks	0.042***	0.088***						
(household level)	(0.011)	(0.017)						
Developed countries	0.263*	−0.268						
	(0.141)	(0.236)						
Travel time to cities	0.009	−0.137*	0.135	0.406**	−3.116***	0.437	−7.820***	0.331
	(0.045)	(0.076)	(0.198)	(0.190)	(0.806)	(0.404)	(1.992)	(2.968)
Control variables W and X	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Panel B: Test and Fit Statistics								
Instrument *F*-test	44.3***	18.7***						
(*p*-value)	(<0.0001)	(<0.0001)						
Wu-Hausman test			0.520	0.660	1.100	1.410	6.960**	1.230
(*p*-value)			(0.598)	(0.515)	(0.551)	(0.494)	(0.031)	(0.542)
R-squared	0.291	0.223						

Note: The sample includes 2,810 households. Normalized household weights are applied to the estimation of all the models. Standard errors are in parentheses, except the two test statistics reported in panel B where the associated *p*-value is in parentheses.

*, **, and *** Significance at the 10%, 5%, and 1% levels, respectively.

regression.[6] Columns (3) and (4) correspond to the second-stage linear regression on the natural log of per hectare output (i.e., yield) and total output of agricultural products, respectively. The log scale helps correct the skewed distributions of the response variables. Columns (5)–(7) correspond to second-stage Tobit regression on fertilizers/pesticides expense, irrigation charge, and hired labor expense, respectively. Column (8) presents estimates from second-stage Poisson regression on the proportion of improved seeds adopted by a household (the estimates are robust to more general specifications, such as negative binomial regression, that are capable of addressing overdispersion).

Results indicate that agricultural output, either on a per hectare basis or in total, is not affected by remittance income. In Nepal, the limited supply and access to fertilizers/pesticides and the limited adoption of improved seeds underlie the story. Most farms in Nepal are subsistence farms. They do not have access to year-round irrigation facilities. The use of quality fertilizer and improved seeds is minimal due to supply constraints. It is widely recognized that most developing countries are confronted with multiple constraints to agricultural production because of poor road infrastructure and communication networks that often prohibit timely distribution of external inputs, thereby reducing the chance of using fertilizers/pesticides or adopting new farm technologies. These constraints are evidenced by the statistical insignificance of remittance effect estimates in the fertilizer/pesticide equation, irrigation expenditure equation, and improved seeds adoption equation.

[6] In the first-stage migration equation, the significantly positive coefficient estimate of the household-level exchange rate shocks arises from the manner in which exchange rate shocks are created. In the NLSS 2003–2004, about 69% of households did not receive remittances, and the exchange rate shock for these households are assigned zero. The large share of zeros is strongly correlated with the zeros in the migration variable, as presented in column (2) of Tables 5 and 6. This result is in sharp contrast to the ward-level analysis in which only 5% of wards did not receive remittances. As a robustness check, we replaced the household-level exchange rate shocks with the ward-level exchange rate shocks in the household-level migration equation and found its coefficient estimate remaining statistically insignificant.

The effect of remittances on labor hiring expense is different from the foregoing factors. It proves to be significantly positive at the 5% level even when the effect of migration is controlled. Although out-migration is likely to encourage rural households to hire more labor to cope with family labor shortage, extra income made the substitution more affordable. Similar findings were discovered by Oldekop et al. (2018). Using data from Nepal's national census and a matching-based regression analysis, Oldekop et al. (2018) found that VDCs with high levels of international outmigration in 2001 experienced substantial increases in local forest cover during 2000–2012, and the effect of outmigration is partly mediated by reductions in the number of months that households dedicate to agriculture, manifesting a migration-induced labor shortage in farming activities.

In general, studies are divided between those arguing that migration undermines agricultural systems and those arguing that labor scarcity can be overcome and remittances are dedicated to land purchases and agricultural improvements (Jokisch 2002). Reviewing earlier evidence, Jokisch (2002) concludes that the dominant thought had been that remittances are more dedicated to family needs and consumption than to investment in agricultural systems. A more recent review of case study evidence by Radel et al. (2019) similarly suggests that migration had relatively weak effects on agricultural activities in Latin America. Nevertheless, the relationship between migration, labor shortages, and agricultural production is highly context-dependent (Davis, Carletto, and Winters 2010). Migrant investment in agriculture, for example, will only take place where market incentives are high, social and physical infrastructure is available, and environmental conditions are favorable; remittances alone cannot overcome most structural obstacles (Radel et al. 2019).

On the household consumption side, results suggest that in Nepal, forest products tend to be inferior goods for which there is decreased demand when income rises. As shown in Table 6, remittance income reduced the number of new rooms made of wood materials (column [3]), a proxy for timber demand, but increased the number of new rooms made of

Table 6
Estimated Remittances Effects on Household Consumption

	First Stage		Second Stage			
			Tobit		Probit	
	Remittances (1)	Migration (2)	Rooms Made of Wood Materials (3)	Rooms Made of Nonwood Materials (4)	Firewood for Cooking (5)	Fossil Fuels for Cooking (6)
Panel A: Parameter Estimates						
Remittances			−1.928*	2.683***	−0.260**	0.691**
			(1.141)	(0.292)	(0.127)	(0.294)
Migration			1.843***	−1.581***	0.247***	−0.742*
			(0.143)	(0.264)	(0.065)	(0.383)
Exchange rate shocks	0.027***	0.081***				
(household level)	(0.009)	(0.013)				
Developed countries	0.551***	−0.188				
	(0.144)	(0.174)				
Travel time to cities	0.030	−0.072	0.782	0.991	1.811	−2.233
	(0.042)	(0.083)	(2.659)	(2.309)	(1.287)	(2.301)
Control variables W and X	Yes	Yes	Yes	Yes	Yes	Yes
Panel B: Test and Fit Statistics						
Instrument *F*-test	41.6***	16.5***				
(*p*-value)	(<0.0001)	(<0.0001)				
Wu-Hausman test			3.640	2.300	0.070	0.520
(*p*-value)			(0.162)	(0.316)	(0.966)	(0.770)
R-squared	0.261	0.207				

Note: The sample includes 3,721 households. Normalized household weights are applied to the estimation of all the models. Standard errors are in parentheses, except the two test statistics reported in panel B where the associated *p*-value is in parentheses.
*, **, and *** Significance at the 10, 5, and 1% levels, respectively.

nonwood materials (column [4]). This result implies that higher remittance income stimulated demand for nonwood materials (e.g., metal and cement) to substitute for timber in housing construction, resulting in a declined demand for timber. Jokisch (2002) notes that construction of housing is seen as a symbol of success by migrants, and that many migrant sending zones have seen housing-related conspicuous consumption. Likewise, the propensity for using firewood for cooking decreased with remittance income (column [5]) and the propensity for using fossil fuels increased with remittance income (column [6]), implying that households receiving more money through remittances were more likely to switch from firewood to fossil fuels such as kerosene and liquefied petroleum gas for cooking. This result is consistent with Baland et al. (2010), who found a negative effect of income growth on firewood collection in Nepal. Oldekop et al. (2018) also found that VDCs with high levels of international outmigration in Nepal experienced a substantial reduction in poverty in Nepal, where the poverty index is partially measured by households' fuelwood consumption. Our result supports the theory that migration, particularly losing labor and gaining remittances, changes the cost-minimizing combination of fuels used to meet household energy needs in developing countries, which depends on energy prices and the value of time (Manning and Taylor 2014).

In summary, the results from exploring household channels suggest that income increase through remittances did not increase demand for agricultural land or forests products. Rather, this income growth motivated farmers to substitute nonwood materials for wood materials in home construction and cooking. Consequently, the pressure on forest resources was relieved.

4. Discussion

The foregoing analysis indicates that remittance income reduced deforestation in the decade 2001–2010. How large is this effect? Our calculation reveals that during this period, remittances reduced deforestation by 4.2 percentage points, accounting for almost 12% of deforestation that occurred in the decade. We base this value on a comparison of the estimated expected deforestation rate between the factual experiment (35.2%) and a counterfactual experiment (39.4%) without the remittances received from households, using the estimated marginal effect of remittances on deforestation (–0.435 as reported in Table 4, column [3c]).

Migration is an enormous phenomenon that has been taking place at various scales throughout the world. Remittances sent by migrants are remarkable capital flows for families of migrants' origins, especially in developing countries (Viet Cuong and Mont 2012). Although the ultimate goal of the migration-to-development strategy would be to end the reliance on migration and remittances (Ellerman 2003), it is likely that migration will remain an important income source and livelihood activity for Nepal in the foreseeable future. Policies should make migration and remittances not only "work for development," for instance, by encouraging productive investment of remittances (McKenzie and Sasin 2007), but also "work for the environment" and "work for sustainability." Taking fuelwood use as an example, remittances help reduce households' fuelwood consumption, but the benefits go beyond forest protection. There are indirect effects on the households, such as spending less time collecting fuelwood (especially by women and youths) and improved indoor air quality by switching to modern fuels; both are relevant outcomes targeted by the United Nations Sustainable Development Goals. In developing nations, 2.4 billion people—more than one-third of the world's population—rely on wood or other biomass fuels for cooking and heating (WRI 2005). Given the extent of fuelwood consumption and depending on the degree to which the effect of remittances as found for Nepal holds for other developing countries, the benefits are potentially enormous.

Findings from the channel analysis are generally consistent with Oldekop et al. (2018). However, our study differs from Oldekop et al. (2018) in at least two aspects. First, our work focuses on the remittances–forest cover change relationship, whereas Oldekop et al. (2018) focus on the migration–forest cover change relationship. Oldekop et al. (2018) discuss three key mechanisms for migration to affect reforestation: two are related to remittances, and one is related to agricultural labor. Our study controls for the effect of agricultural labor and focuses on the remittances-mediated effect on deforestation. In a sense, our study extends Oldekop et al. (2018) with an in-depth follow-up analysis of the remittances-related channels of impact of migration.

Moreover, our study focuses on detecting deforestation rather than reforestation (or afforestation) as in Oldekop et al. (2018). According to Rudel et al. (2005), deforestation takes place when people clear land of trees and regrowth does not occur, afforestation occurs when forest cover expands through the planting of trees on lands without trees, and reforestation occurs when forests spontaneously regenerate on previously forested lands. The decision-making around deforestation may vary from that of afforestation or forest regeneration, resulting in different drivers of the two types of forest cover change, though they are related. Combining the insights from both studies offers a more complete picture of what happened to the forest cover in Nepal; that is, there is indication that migration flows and remittances have jointly resulted in a reduction in forest clearing and an increase in reforestation during the first decade of the twenty-first century.

In this study, we demonstrate the positive role of remittances in reducing deforestation in Nepal. This win-win effect of remittances provides a potential policy opportunity to address poverty and the conservation of valuable natural resources concurrently. This finding is in sharp contrast to El Salvador, where a remittance economy with few agricultural investment opportunities within reach of migrant families is found to cause a contraction of farming activities and associated forest expansion (Hecht et al. 2006; Hecht and Saatchi 2007). Future research is needed to test whether the finding is context-dependent and to what degree the effect of income increase through remittances holds for other developing economies. Moreover, the question of how to get involved merits future research to inform polices on capitalizing on the win-win link. While polices encouraging migration itself might be considered controversial, policies that encourage remittances directly (McKenzie and Sasin 2007) or more productive and environmentally conscious use of remittances seem rational. Moreover, policy options that influence the channels between migration or remittances and outcomes (such as agricultural output, household welfare, land use, and natural resource management) also deserve attention.

5. Conclusion

This article provides new evidence that income increase through remittances can ease pressure on forest resources. We find that remittance income reduced deforestation by almost 12% of the total forest loss in Nepal during 2001–2010. There is little evidence that remittances induced competition for land through increased modern input (e.g., chemical fertilizers and pesticides, irrigation, improved seeds) or stimulated demand for forest products. Remittance income did, however, increase expenditure on hired labor in farming activities. It also resulted in a switch of household consumption from timber and wood products to nonforest products in housing construction and cooking. These findings draw from a comprehensive data set, including high-quality land use data and an extensive national household survey. The estimated effects are robust across a variety of specifications and estimation methods, providing a strong ground for evidence-based policy recommendations.

This study contributes to the debate about potential tension or synergy between development and conservation. The widespread transfer of monies from foreign workers to their home countries—the sending of remittances—is among the largest of global capital flows and occurs throughout Africa, the Middle East, Asia, and Latin America (Hecht 2010). These remittances directly augment the income of those receiving households, significantly reducing poverty around the world. Rural development and conservation debates must consider the environmental ramifications of migration and remittance economies, taking into account the dynamic interactions among micro- and macroprocesses that shape policies and individual actions.

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