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Off-Farm Employment, Forest Clearing and Natural Resource Use: Evidence from the Ecuadorian Amazon

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Abstract: Off-farm employment in rural households has been cited in the literature as a potentially ideal alternative to reduce forest clearing and pressure on natural resources, since it provides income while at the same time taking household labor away from the farm. Nonetheless, empirical research on the relationship between off-farm work and natural resource use is still scarce. This paper examines the impact of off-farm work on forest clearing, logging, hunting, and fishing among both migrant colonists and indigenous populations in the Ecuadorian Amazon. In contrast to prior research, we use an instrumental variable approach to control for the potential endogeneity of off-farm work with respect to natural resource use. The results indicate that the higher the number of days worked off-farm at the household level, the lower the forest clearing. On the other hand, the number of days worked off-farm has no effect on logging, hunting, and fishing. The implications of this for sustainable development and conservation are explored in the conclusion section.

Keywords: off-farm work; forest clearing; forest resources; endogeneity; Amazon Ecuador

1. Introduction

For some decades, researchers and development practitioners have been aware of the substantial contributions of off-farm employment to the livelihoods of rural peoples in developing countries [1]. Off-farm work employs 10–30% of the rural labor force and accounts for 35–40% of rural household incomes in developing countries [2]. Given these figures, it is not surprising that significant research continues to focus on analyzing further the determinants and implications of off-farm work. This has included assessing the impact of off-farm employment on rural poverty [3,4], income inequality [5,6], agricultural investment and farm technology [7,8], food security [9], and women's inclusion in the economy [10]. However, the relationship between off-farm employment and the environment reflected in natural resource use (i.e., agriculture, timber extraction, hunting, and fishing) has received far less attention because of the little work on forest environments.

A major concern in this type of study is that an endogeneity problem may arise if off-farm work is correlated with unobserved characteristics (unobserved heterogeneity) that also affect household livelihood decisions [7,9]. Failing to control for the potential endogeneity between off-farm work and forest resource use may result in biased estimators.

In the course of analyzing the determinants of natural resource use including forest clearing, a number of prior studies have found a negative relationship between off-farm employment, on the one hand, and deforestation [11,12], hunting [13,14], fishing [15], and use of non-timber forest products, [16], on the other. However, none of these studies took into account the potential endogeneity of off-farm employment with respect to natural resource use, which would lead to biased findings if endogeneity is present.

In contrast to previous studies, this paper examines the impact of off-farm work on natural resource use using an instrumental variables approach to take into account the possible endogeneity. We use data from a survey conducted among migrant-colonist and indigenous households in the province of Pastaza, in the central Ecuadorian Amazon. The Ecuadorian Amazon is particularly interesting for conducting this study because: (1) the region is experiencing high deforestation and undergoing profound socioeconomic changes resulting from large government investments on road infrastructure, health, and education, which have increased off-farm opportunities for the rural population [17]; and (2) it is one of the world's biodiversity hotspots [18], so habitat destruction/degradation has potentially profound implications for biodiversity.

The paper is organized as follows: the next section provides a brief literature review, including theoretical perspectives and relevant previous empirical studies. This is followed by descriptions of the research area, the survey data collected, and the variables used in the empirical work. Then the statistical estimation methodology is presented, followed by the results and conclusions.

2. Literature Review

2.1. Theoretical Background

Rural livelihoods in developing countries are determined by a variety of assets (human, natural, physical, financial, and social capital) that households have and invest, which can be in a diverse portfolio of activities, including agricultural work on their own farm and off-farm employment (agricultural or non-agricultural) [19]. Participation in off-farm activities is sometimes driven by necessity, which may be related to situations or events that threaten household livelihoods (i.e., land fragmentation, environmental deterioration, natural disasters, civil conflicts/wars), or by choice (having access to higher wages/incomes in off-farm work) [20,21].

According to the economic theory of the agricultural household [22,23], rural households seek to maximize income subject to constraints including available labor, capital, and technology. The degree of diversification is thus a function of the returns of labor time spent on on-farm activities in comparison to off-farm activities. With a fixed quantity of farm assets (land and infrastructure) and available household labor, a household compares the returns and chooses between allocating labor to farm work versus off-farm activities. Committing time to off-farm activities reduces time available for agricultural activities, including clearing forests. Therefore, off-farm employment may contribute to environmental conservation by drawing off labor which could otherwise be used to farm and to clear forests [24–26].

Since off-farm employment usually provides higher earnings than small-scale farming [27,28], it may contribute to environmental conservation in two ways: first, by relaxing households' need to use natural resources to obtain food and other needs [29]; and second, by providing farmers with additional income that could be used, inter alia, to adopt improved technologies or new crops that increase the value of output per unit of land, which may or may not be more compatible with conservation [30]. Nevertheless, higher incomes from off-farm activities could also lead to greater pressures on natural resources if used to expand the agricultural area or extract more timber [31], or to harvest more wildlife or fish than would otherwise occur (through buying chainsaws or improved firearms or fishing equipment) [32].

2.2. Previous Empirical Studies

Empirical studies to date report mixed results concerning the relationship between off-farm employment and natural resource use. Pichón [12] and Pichón and Bilsborrow [33] investigated land use patterns of migrant-colonists in the northern Ecuadorian Amazon based on 1990 survey data, finding that households engaging in off-farm employment converted less land to crops and pasture than those that only worked on the farm. In Honduras, Godoy et al. [11] found that the share of income coming from off-farm sources was negatively related to the area of forest cleared by a household. In the Brazilian Amazon, Perz [34] found that having "business income" reduced the proportion of land in crops and pasture.

Similarly, concerning the implications for hunting, Vasco and Sirén [13] found higher shares of income from off-farm employment associated with lower harvests of wild meat among indigenous peoples in the Ecuadorian Amazon. Moreover, Sirén and Parvinen [16] found that increased income from participation in off-farm employment reduced harvests of wildlife and palm trees in indigenous communities of the Ecuadorian Amazon. Meanwhile, in the Philippines, Shively [14] found that non-agricultural employment has a negative effect on both the likelihood of hunting wild animals and the number of hunting trips.

On the other hand, various other studies report no net effect of off-farm income on natural resource use. Combining satellite imagery and household survey data, Mena et al. [31] found no significant effect of off-farm employment on deforestation rates in the Northern Ecuadorian Amazon. Nevertheless, the authors speculate that improved off-farm work opportunities may trigger deforestation in the long-run, as off-farm earnings may be used for the extensification of agriculture by financing land purchase and land clearing. In the Brazilian Amazon, Caviglia-Harris and Sills [35] found no evidence that income diversification and its inherent competition for household labor reduces deforestation at the household level. Finally, a few studies have found a positive effect of off-farm employment on deforestation and timber extraction. For instance, Montoya et al. [36] investigated the determinants of land use in the Peruvian Amazon, finding that households receiving off-farm income had more land in crops than other households, likely for the reasons mentioned above.

While some of the studies cited above mention the potential endogeneity of off-farm work in studies of deforestation and the use of forest resources, none addresses it. Thus, we build upon this literature by incorporating an instrumental variable approach to control for the potential endogeneity of off-farm employment with respect to forest resource use.

3. Data and Variables

3.1. The Study Area

The study was conducted in Pastaza, Ecuador's largest but least populated province. The westernmost part is mostly populated by colonists who migrated to the Amazon during the 1960s, while the Eastern part is sparsely occupied mainly by indigenous populations. Colonists represent 38% of Pastaza's rural population while indigenous peoples account for the rest, principally Kichwa and Shuar [37]. Most colonists engage in the cultivation of cash crops, including sugar cane, *naranjilla* (a native citrus fruit) and *taro* (locally known as *papa china*), as well as cattle ranching. Although indigenous peoples practice subsistence agriculture (cassava and plantain), most also engage in limited commercial agriculture [38]. Because of factors such as isolation from city centers and markets, lack of agricultural extension, and low soil fertility, agricultural incomes in the Amazon are considerably lower than those in the Highlands or the Coast of Ecuador, the other two major geographical regions of Ecuador [39,40]. From 2001 to 2010, Pastaza's rural population increased by 25%, which has resulted in increased deforestation and pressure on natural resources [41,42].

In this context, it is not surprising that a significant share (67%) of the rural population has chosen to diversify its sources of income [43]. This process has been catalyzed by large government investments in road infrastructure, education, and health, which have substantially increased the availability of qualified (school teacher, government official) and non-qualified (e.g., bricklayer, janitor, foreman) public sector jobs [44]. In addition, the improvement and expansion of the road system has facilitated the mobility of rural residents to work in urban areas [45].

3.2. Survey Data

The data come mainly from a household survey conducted in the province of Pastaza in May-October 2013. The questionnaire was designed to obtain information on household demographic characteristics, land use, household assets, and natural resource use, as well as on-farm and off-farm work effort and income. The sample used involves two-stages. First, the selection of communities using *controlled sampling* [46,47], which is appropriate when only a modest number of sample points can be selected based on the resources available, but taking into account multiple criteria simultaneously, involving some judgment. Thus, in the first stage, 18 communities (see Table 1) were selected to represent the diversity of populations and livelihood-seeking behavior in the study region in terms of ethnicity, distance to markets and other infrastructure, population density, and availability of off-farm and non-farm employment [48]. Then, in the second stage, households within a community were selected using random sampling from a list of households in each community. The final sample was constituted by Kichwa (116), Shuar (120), and colonist (68) households. The survey was administered to the household head and/or spouse, whoever was available. A total of 304 households were interviewed in the 18 communities (see Figure 1). While not strictly a probability sample, since the communities were not selected in a random fashion, the sample should still provide a good representation of households and their livelihoods in the study area. Note that Puyo is the provincial capital and only city in the study region, with a population of 62,000 in the most recent population census, in 2010 [37].

Table 1. Communities in the sample.

Community	Population	Predominant Ethnic Group	Accessible by	Time Needed to Reach Puyo (hours)
Comuna 6 de Diciembre	45	Colonist	Dirt road	3.5
Boayacu	50	Colonist	Dirt road	1.0
Unión del Llandia	180	Colonist	Dirt road	0.5
Simón Bolívar	3000	Colonist	Paved road	0.5
Centro Yu	50	Shuar	Dirt road	1.5
Shiram Popunas	141	Shuar	Trail	6.0
Sharupi	94	Shuar	Trail	3.0
Chapintsa	420	Shuar	Dirt road	2.0
Pitirishka	250	Shuar	Paved road	0.75
Chubitayu	1125	Shuar	Paved road	1.0
Iskayaku	60	Kichwa	Trail	3.0
Shiwa Kucha	310	Kichwa	Dirt road	2.0
Jaime Roldós	75	Kichwa	River	8.0
Killoalpa	75	Kichwa	River	8.0
Nuevo San José	150	Kichwa	River	8.0
Santa Cecilia	150	Kichwa	Dirt road	3.5
Canelos	1200	Kichwa	Dirt road	1.0

3.3. The Context: Off-Farm Employment in Pastaza

Table 2 shows the share of household income by ethnic group, estimated with data from the household survey. We divided household income into that resulting from on-farm household agricultural labor and that from off-farm activities. The first includes income from growing subsistence and cash crops, raising livestock (almost exclusively cattle), while the latter comprises off-farm agricultural wage employment, self-employment (mainly running small grocery stores or *tiendas*, cooking meals, and selling handicrafts), and off-farm non-agricultural wage employment. On average, off-farm employment accounts for over half of the total household income. The shares of income from off-farm agricultural wage employment and self-employment differ little among ethnic groups, although Kichwa households depend more on off-farm non-agricultural wage employment and, overall, on off-farm work than colonist and Shuar households. In contrast, colonists earn their livelihoods principally from agriculture, which is likely related to their focus on cash crop production, far more profitable than the traditional subsistence farm practices of indigenous peoples.

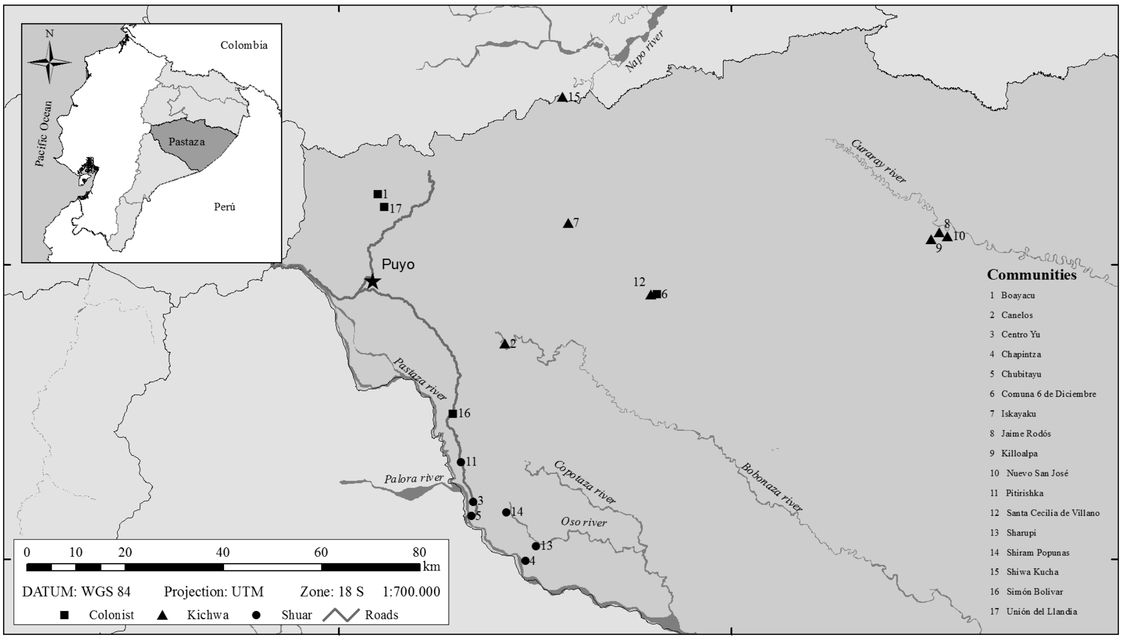

Figure 1. The study area in the central Ecuadorian Amazon.

Table 2. Share of households' income by type of work and ethnic group (%).

	Colonist	Kichwa	Shuar	Total
On-farm household agricultural labor	54	41	49	47
Off-farm (total)	46	59	51	53
Off-Farm agricultural wage employment	14	14	17	15
Self-employment	6	7	6	7
Off-farm non-agricultural wage employment	26	38	28	31

Table 3 shows the average annual income by type of employment and ethnic group, estimated with data from the household survey. With the exception of off-farm agricultural wage employment, off-farm work yields higher incomes than on-farm household agricultural labor, with off-farm non-agricultural wage work having the highest wage rates. The Shuar have higher mean earnings from on-farm work and from self-employment. Colonists' mean off-farm agricultural wage income is higher than that of the Kichwa and Shuar. A likely explanation is that agricultural wages are higher close to urban areas, where most colonists are settled. The average income of Kichwa non-agricultural wage workers is higher than that of colonists and Shuar, which is due to an important fraction of the Kichwa working as school teachers and public employees (see Table 4), who tend to be better paid. Overall, colonists have higher incomes than indigenous peoples, though the difference is much less than popularly thought.

Table 3. Mean annual income by employment category and ethnic group (US $) (Since 2000 Ecuador adopted the US Dollar as its official currency).

	Colonist	Kichwa	Shuar	All Ethnic Groups
On-farm household agricultural labor	2143	1984	3126	2489
Off-farm				
Off-Farm agricultural wage employment	2226	1593	1453	1663
Self-employment	3407	2741	5564	3936
Off-farm non-agricultural wage employment	5751	5902	5060	5440
Total income	4136	3383	3851	4286

Table 4. Job categories by ethnic group (%).

	Colonist	Kichwa	Shuar	Total
Agricultural wage earner	31.1	50.0	35.9	39.0
Domestic servant	9.8	0.0	6.8	5.4
Soldier	1.6	0.0	6.8	3.3
School teacher	8.2	25.0	21.4	19.1
Public employee	16.4	9.7	7.8	10.4
Bricklayer	6.6	1.4	3.9	4.6
Carpenter	1.6	1.4	2.9	2.1
Chainsaw operator	0.0	0.0	4.0	1.7
Driver	6.6	0.0	0.0	1.7
Guide	0.0	2.8	1.0	1.2
Other	14.8	9.8	10.7	11.1

Most of the wage earners in the sample are engaged in off-farm agricultural wage work, which employs 50%, 31% and 36% of the Kichwa, Shuar, and colonists, respectively (Table 4). An important share of the Kichwa and Shuar wage earners (25% and 21%, respectively) are employed as school teachers, while around 10% occupational distribution is linked to large government investments in education and the decentralization of public services, increasing off-farm job opportunities for indigenous peoples in the Amazon [43]. A third of the colonists are employed in low-paid non-agricultural jobs (domestic servant, bricklayer, driver, and janitor), which partly explains why off-farm earnings are lower for colonists than they are for the Kichwa and Shuar. About 7% of the Shuar are engaged in timber-related activities (carpenter and chainsaw operator), consistent with timber extraction being greater in Shuar territories. This may be related to the Shuar being primarily migrants to Pastaza and feeling less tied to the land.

4. Statistical Estimation Methodology

4.1. Empirical Model

We use multivariate analysis to estimate the impact of off-farm work on forest resource use at the household level. However, a methodological issue must be addressed before proceeding. As mentioned earlier in the text, caution is needed in statistically estimating the impact of income diversification on forest resource use, since participation in off-farm work may be correlated with unobserved characteristics also influencing natural resource use decisions. This may happen, for instance, if households participating in off-farm work are more ambitious and industrious, and thus also engage in more farm work and more forest clearing. If so, failing to control for endogeneity may result in an upward bias in the effect of off-farm employment on forest clearing. On the other hand, if a household taking part in off-farm work does so because it has a taste for market work instead of farm work, the results will have a downward bias [49]. Instrumental variables are commonly used to address endogeneity problems. The idea behind this methodology is to find variables (instruments) that capture the effect of off-farm employment but do not directly affect the dependent variable (e.g., forest clearing), which allows for an estimation of coefficients that satisfies the conditions for consistency.

Besides endogeneity, another issue must be addressed. The four dependent variables (area of cleared forest during the last 12 months and the amounts of timber, wild meat, and fish harvested the year preceding the survey) are all continuous variables, taking on the value of zero for a non-trivial fraction of the sample. Using an ordinary least squares (OLS) approach for this kind of "*corner solution outcomes*" tends to yield inconsistent estimators [50]. We therefore use a Tobit model, in which the observed dependent variable Y takes the value of 0 if the latent variable $Y^* \leq 0$, and the value of Y^*

if $Y^* > 0$. Since the results of Tobit models are not directly interpretable, we estimate and report the marginal effects at the unconditional value of Y. Thus, we use an IV Tobit model of the following form.

$$Y^*_i = E_i\beta + X_i\gamma + \mu_i \tag{1}$$

$$E_i = X_i\theta_1 + Z_i\theta_2 + \upsilon_i \tag{2}$$

where

$$Y_i = 0 \text{ if } Y_i^* \leq 0$$

$$Y_i = Y_i^* \text{ if } Y_i^* > 0$$

and where i = household number = 1, . . . , N, E is the endogenous predictor of interest, X is a vector of exogenous predictors to be described later on, Z is a vector of instrumental variables that satisfy the conditions of explanatory power and exogeneity, β and γ are vectors of structural parameters, and θ_1 and θ_2 are matrices of reduced-form parameters. The model assumes that $(\mu_i, \upsilon_i) \sim N(0)$.

4.2. Dependent and Independent Variables

Definitions and descriptive statistics are presented in Table 5. The dependent variables are the area of cleared forest (primary or secondary) and the volume of timber harvested the year preceding the survey. It is worth noting that forest clearing does not necessarily involve timber harvesting [51]. Forest clearing is normally done to plant cash crops (*naranjilla*) and pastures but does not necessarily entail timber harvesting. In fact, in a study conducted in the northern Ecuadorian Amazon, Muzo et al. [52] found that only 38% of the households that cleared forest actually sold the timber from the cleared plot while, on the other hand, many smallholders practice selective logging, which does not necessarily require clearing the whole plot. The other two dependent variables are the amounts of wild meat and fish harvested during the twelve months preceding the survey. As stated earlier, the independent variable of interest is the number of days worked off-farm by household members during the 12 months preceding the survey.

The specification of estimation equations is based on household and contextual predictors. The first group of independent or explanatory variables includes the age and the education of the head, both expressed in years. Two dichotomous variables take the value of 1 if the household head is Kichwa or Shuar, to account for the effect of ethnicity, with colonists taken as the omitted or comparison (=0) group. Since natural resource use may be affected by household labor availability, as well as consumption needs, the model also includes household size, which is divided into male adults, female adults, and children, taken to be those under age 15 (see Table 5). A wealth index controls for the effect of capital on the dependent variables. The wealth index is the first principal component of ownership of a radio, TV, cell phone, computer, gas stove, refrigerator, spray pump, car, motorcycle, solar panel, boat, and rifle. The first principal component accounted for 29% of the variation in wealth across the study households. We prefer using this statistical approach to using simple count indices, e.g., assigning equal values to every asset, since it gives more weight to assets having more discriminatory power in terms of differentiating household wealth [53,54]. While there is a possibility that reverse causality and thus simultaneity exist between wealth and natural resource use, the wealth index used here is a construct of assets accumulated over a relatively long period of time, which greatly reduces the risk of endogeneity. The natural logarithm of total farm area is included as a proxy for natural capital. Finally, the distance from the dwelling to the nearest road is included to control for the effect of accessibility.

At the community level (contextual level), we explore the effects of travel time to Puyo (the provincial capital and only city in the province) by the usual means available to members of the community to control for access to markets. Population density, expressed as inhabitants per km^2, accounts for the overall effect of population pressures on natural resources in the area. Finally, a dummy variable taking the value of 1 is included to capture the effect of whether the community received money (to preserve the forest, as a payment for ecosystem services) from the incipient governmental "*Plan Socio Bosque*" conservation program (The "Plan Socio Bosque" is a government conservation program which rewards land owners, including indigenous communities, who agree to preserve their native forest [55]).

4.3. Instruments

A valid instrument must fulfill two conditions: it must be (a) fairly highly correlated with the endogenous variable, but (b) must not directly affect the outcome variable, *except* through the endogenous variable—or, in other words, it must not be correlated with the error term. The first condition can be tested by regressing the potential instruments on the suspected endogenous variable to measure their explanatory power. As for the second condition, below we proceed to introduce our two instruments and justify their use based on theoretical grounds. In the results section we also report the Sargan and Bassman overidentification tests.

Our suspected endogenous variable is the total number of days worked off-farm by the members of a household during the 12 months preceding the survey, and the selected instruments are (1) the share of population having social security insurance and (2) the mean weekly hours worked off-farm by persons aged 15–59 (This variable is the result of dividing the total estimated hours worked off-farm by the parish population aged 15–59), both measured at the *parroquia* or parish level (smallest recognized administrative unit) based on data from the latest Census of Population, in 2010 [37]. This strategy is consistent with some previous research using aggregate variables computed from lagged data as instruments for off-farm employment [7,56]. For instrument (1), the theoretical justification is that the higher the coverage of social security insurance in a parish, the higher the availability of off-farm jobs, since it is those jobs that tend to come with social security insurance (both public and formal private sector jobs). A third of the off-farm workers in our sample are in fact public sector employees (including school teachers and military) who by law must be covered by public insurance. In addition, Ecuadorian law fines employers who fail to register their employees in the government social security system. Having social security is thus mostly a decision that workers cannot decide by themselves, and therefore should not have any direct influence on natural resource use. Concerning instrument (2), the average weekly hours that people work off-farm should reflect off-farm opportunities at the parish level and therefore affect the households' possibility of engaging in off-farm work. Neither should directly affect forest clearing. However, it is possible that the mean hours worked off-farm may be correlated with other factors, such as proximity to markets and population density, which also influence natural resource use. To control for this, we include distance to market and population density in the model. It should also be noted that we use lagged aggregates at the parish level to further dilute the possible endogeneity of this instrument [7].

Table 5. Definitions and descriptive statistics.

Variable	Description	Mean	St. Deviation
Dependent variables			
Cleared land	Land cleared in the 12 months preceding the survey (ha) (Cleared land, timber, hunting, and fishing harvested are self-reported values collected by interviewers. Prior research in the Amazon [13,57] found self-reported values reasonably accurate and consistent with other measurement methods (i.e., direct measurement.)	0.72	1.47
Timber	Volume of timber harvested in the 12 months preceding the survey (m^3)	21.31	89.35
Hunting	Wild meat harvested in the 12 months preceding the survey (kg)	48.19	102.04
Fishing	Fish harvested in the 12 months preceding the survey (kg)	78.51	253.74

Table 5. *Cont.*

Variable	Description	Mean	St. Deviation
Independent variables			
Days worked off-farm	Days worked off-farm by household members in the past 12 months.	263	232
Age	Age of head	41.3	13.9
Education	Education of head (years)	8.33	4.36
Kichwa (0/1)	Head is Kichwa	0.38	0.48
Shuar (0/1)	Head is Shuar	0.39	0.48
Colonist (0/1)	Head is mestizo	0.23	0.40
Adult men	Male household members older than 15 years	1.42	0.93
Adult Women	Female household members older than 15 years	1.34	0.76
Children	Household members younger than 15 years	1.80	1.73
Wealth	Wealth index	0.01	1.87
Farm size	Farm size (ha), ln	88.36	347.85
Distance to road	Distance to the nearest road (km)	14.19	34.74
Community predictors			
Distance to market	Travel time to Puyo (minutes)	299.70	775.09
Population Density	Population density (inhabitant/km^2)	17.57	60.68
Socio Bosque (0/1)	Community takes part in Socio Bosque program	0.09	29.59
Instruments			
Social security	Share of individuals in parish with social security estimated from National Census 2010	0.26	0.04
Hours off-farm	Average number of hours worked off-farm by adults in parish estimated from Census 2010	2.80	0.87

Note: (0/1) identifies dummy variables.

5. Results and Discussion

5.1. Validity of Instruments

Since there are no appropriate tests to measure the validity of instruments with IV Tobit models, we alternatively ran 2SLS regressions and estimated the explanatory power and overidentification tests for the selected instruments. Table 6 shows the first stage regression for the number of days worked off-farm by household members. The test of joint significance of instruments yields an F statistics of 15 (p = 0.000), which exceeds the rule of thumb proposed by Staiger and Stock [58]—according to which instruments are not weak if their joint significance in the first stage regression yields an F statistics larger than ten—and the critical value provided by Stock and Yogo [59] (13.46) for one endogenous predictor and two instrumental variables. In Table 7 we also report the results of the Sargan and Bassman overidentification tests, which in all cases fail to reject the null hypothesis that the instrumental variables selected are not correlated with the error term. Hence, we concluded that our instruments are highly correlated with the number of days worked off-farm at the household level, while they do not directly affect the dependent variables under analysis. This is what is required for them to identify the equation for the endogenous dependent variable, days of work off-farm during the past 12 months.

Table 6. First stage regression for the number of days worked off-farm.

Variable	Coefficient
Age	3.724
Age square	−0.065
Education	6.868 **
Kichwa (0/1)	−12.554

Table 6. *Cont.*

Variable	Coefficient
Shuar (0/1)	1.714
Adult men	5.519
Adult Women	9.928
Children	−22.030 **
Wealth	19.499 **
Farm size	−18.764 *
Distance to road	26.951
Distance to market	−15.973
Population Density	−1.033
Socio Bosque (0/1)	74.559 +
Social security	31.106 *
Hours off-farm	394.902 **
R^2	0.31
Joint significance of instruments (Prob > F)	15 **

Note: +, * and ** stand for significance at the 0.1, 0.05, and 0.01 levels, respectively. (0/1) identifies dummy variables.

5.2. Statistical Results

Table 7 presents the marginal effects of the Tobit and IV Tobit regressions estimated at the unconditional value of the dependent variable in each case. Both the Tobit and the IV Tobit regressions show a negative and significant effect (at 95% probability) of off-farm work on the total area of cleared forest. The coefficient of the IV Tobit is larger in magnitude, which suggests the existence of a downward bias if endogeneity is not controlled for. An increase of 100 days worked off-farm leads to a reduction of 0.2 ha in the area of cleared forest in the previous 12 months, that is, from a mean of 0.72 to 0.52.

The case of fishing is different. While the Tobit model yields a negative and significant effect of off-farm work on fishing, the coefficient of days worked is no longer significant once endogeneity is controlled for, suggesting an endogeneity bias when assessing the impact of off-farm work in the absence of instrumental variables. On the other hand, regardless of the methodology utilized, results show that off-farm employment has no effect on the amounts of timber and game harvested. Altogether, the non-significant coefficients may reflect that extracting timber, hunting, and fishing do not directly compete with off-farm employment for household labor. This is likely, since timber is normally sold to dealers who take care of the transport and sometimes of the extraction as well [52], while hunting and fishing can be done on weekends and free time. Farming, on the other hand, demands more labor time, and, since in the Amazon context forest clearing is done mostly for agricultural purposes, households participating more in off-farm work do not need to clear large areas of forest. Overall, the results for the effect of off-farm employment indicate that, in the absence of instrumental variables, the regressions may yield biased estimators, which in turn may lead to misleading interpretations. So, controlling for the potential endogeneity of off-farm employment with respect to natural resource use is justified.

Table 7. Determinants of forest clearing and harvest of timber, game, and fish with share of income from off-farm work as instrumented variable (marginal effects at the unconditional value of y).

	Forest Clearing		**Timber**		**Hunting**		**Fishing**	
	Tobit	**IV Tobit**	**Tobit**	**IV Tobit**	**Tobit**	**IV Tobit**	**Tobit**	**IV Tobit**
Household predictors								
Days off-farm	−0.000 *	−0.002 *	−0.012	0.016	−0.001	0.056	−0.121 **	−0.192
Age	−0.045	−0.044	−1.278	−0.133	1.562	1.509	−5.248	−5.203 +
Age squared	0.000	0.000	0.011	0.012	−0.020	−0.017	0.041	0.038
Education	−0.012	−0.005	−1.719 *	−1.944 **	0.793	0.336	0.080	0.658
Kichwa (0/1)	−0.416 *	−0.378 *	−0.747	−1.288	28.120 *	28.80 *	43.877	45.468
Shuar (0/1)	−0.125	−0.044	21.132 +	19.815 +	−4.274	−5.192	17.102	20.571
Adult men	0.004	0.006	−1.960	−1.982	3.591	3.906	4.874	4.712
Adult women	0.079	0.100	4.169	3.886	1.419	0.508	22.726	23.760
Children	0.009	−0.018	1.640	2.233	4.777 *	6.136 **	13.196 *	11.670 **
Wealth	−0.004	0.032	−0.030	−0.733	−8.083 **	−9.616 **	−8.151	−6.307
Farm size	0.170 **	0.163 **	7.179 *	7.52 *	5.523	5.940	3.002	2.563
Distance to road	−0.500 **	−0.453 **	−20.873 **	−22.101 **	5.999	4.088	13.216	15.549
Community predictors								
Distance to market	0.328 **	0.272 *	10.463 +	11.889 *	14.152 *	17.33 **	16.023	13.014
Density	−0.011 **	−0.010 **	−0.403 *	−0.399 **	−0.199	−0.168	−1.182 **	−1.198 **
Socio Bosque (0/1)	1.639	1.399	−69.74 *	−71.19 *	−30.062 **	−29.206 **	−12.227	−17.519
Wald test	63 **	49 **	73 **	51 **	164 **	132 **	132 **	111 **
Number of observations	304							
Uncensored observations	47%		38%		44%		67%	
Sargan test (*p*-value)		0.612		0.721		0.566		0.988
Bassman test (*p*-value)		0.622		0.728		0.577		0.989

Note: +, * and ** stand for significance at the 0.1, 0.05, and 0.01 levels, respectively. (0/1) identifies dummy variables. All models were estimated with robust standard errors. Sargan and Bassman overidentification tests estimated from 2SLS regressions.

In evaluating the results of the statistical models, it is also important to briefly examine the effects of the additional, control variables. If the results are implausible, that casts doubt on the findings for the main variables of interest. Among the control variables, education has a negative effect on timber harvest, which may suggest that investing in human capital may have a positive effect on forest conservation, though it does not affect forest clearing (as observed before in the northern Ecuadorian Amazon by Pichón & Bilsborrow (1999)), hunting, or fishing. Ethnicity variables are also consistent with a priori expectations: On average, Kichwa households clear 0.4 less forest than their colonist and Shuar counterparts. A possible explanation is that, unlike the colonists and the Shuar, who are more involved in agricultural markets and have larger areas of crops and pastures [60], the Kichwa depend more on subsistence agriculture, and thus do not need to clear as much forest. Consistent with this and prior research [13,61], Kichwa households also depend much more on consuming wild meat, harvesting, on average, 28 kg more wild meat per year (at least 50% more) than colonist and Shuar households. The results also show that Shuar households harvest more timber than their colonist and Kichwa counterparts. However, this difference is only marginally significant (at 90% probability).

In terms of the effects of other household variables, first, there are no meaningful effects due to the age of the household head; and, surprisingly, there are also no significant effects due to the numbers of adults (males or females) on any of the four dependent variables once other variables have been controlled for. On the other hand, on average, an additional child increases the harvest of game and fish by 6 and 11 kg, respectively, which may reflect a desire to provide more protein for the household when there are children and/or to hunt and fish as a joint activity involving a parent and child, which is consistent with the transmission of cultural values even when providing children with a more formal education.

Moving on, wealthier households harvest less game, which is fully consistent with prior studies [13,61] and may reflect that they have access to alternative sources of protein and fat, and hence do not depend on game and fish to meet their dietary needs. Households with larger farms tend to clear more forest and to harvest more timber (easier from their own land), which indicates that larger farms are likely to have more land with forest. Households near roads clear more forest and harvest more timber. These findings are consistent with prior research on colonists [62] showing that the proximity to roads facilitates the transport of timber and agricultural produce to markets, increasing the motivations to both clear forest for agriculture and sell timber.

At the community level, the longer the travel time to Puyo, the larger the area of cleared forest by households in the community, and the more timber and game harvested. This appears to contradict expectations, as it means the community is farther from the market, but it is likely due to the greater availability of forest and game in more isolated, less intervened areas (unlike the communities close to Puyo). In the case of game, it is also possible that households living closer to urban areas are more likely to access other food sources for consumption, and also have little game to hunt. Households in densely populated communities clear less forest and harvest less timber and fish, which likely reflects the depletion of these resources and perhaps a greater competition for what remains, due to the higher population pressure.

Finally, the "*Socio Bosque*" dummy is negative and significant only for the amount of timber sold. Households in communities participating in "*Socio Bosque*" harvest, on average, 71 m^3 less timber than those not in the program, as hoped for in the Socio Bosque program. However, *Socio Bosque* has no effect on the area of cleared forest. A possible explanation is that clearing forest is mostly done to increase the agricultural area, which is a longer-term process and mostly done before the reference period, while selling timber is more of a discretionary variable, to cut as needed. These results may indicate that payments for ecosystem services have more impact on those who clear forest mainly to extract and sell timber than for those who clear forest for agriculture. Although the Socio Bosque program focuses on the preservation of forest rather than wildlife conservation, and prior research [63] suggests that, in its current form, it has neglected the conservation of animal species, our results suggest that it may contribute to reduce wildlife harvesting, likely due to the fact that beneficiaries of "*Socio Bosque*" are not allowed to hunt for commercial or recreational purposes. In any case, the effects of "*Socio Bosque*" on wildlife conservation warrant further research, which is beyond the scope of this paper.

In general, our findings for control variables are plausible, so the overall results show that promoting off-farm employment for rural households may be a useful strategy to reduce deforestation in the Amazon, since it offers higher earnings than on-farm work. On the other hand, off-farm work has no effect on reducing the harvesting of forest products, likely because the latter involves little time and hence does not directly compete with off-farm work for household labor.

6. Conclusions

This paper has analyzed the effect of off-farm employment, proxied by the number of days worked off-farm by members of the household in the previous 12 months, on natural resource use in the Ecuadorian Amazon. After controlling for the potential endogeneity of off-farm employment with instrumental variables, we find that off-farm work reduces the area of forest cleared in the previous 12 months. We interpret this as being due to the higher opportunity cost of labor in off-farm work vs. farm work. At the same time, off-farm employment has no significant effect on the harvesting/extraction of timber, game, or fish, probably because these occasional activities can be carried out in the traditional way involving little time, and hence do not directly compete with off-farm work for household labor.

Other than these findings, this research also offers some key messages for development and conservation practitioners. First, off-farm employment may be a useful tool to integrate rural development and the conservation of forests in the Amazon, since it offers higher earnings than farm work and has the additional effect of reducing forest clearing. It is thus a win-win policy, given its economic and environmental effects. However, since it has no effect on the harvesting of timber, game, and fish, different strategies are needed to tackle any observed overuse of these resources. In the case of timber, investments in human capital (education) and payments for ecosystem services appear to be useful policies, such as the Socio Bosque program in Ecuador.

Because off-farm employment tends to reduce poverty, policy-makers should stimulate or at least facilitate the expansion of off-farm non-agricultural employment for the rural population to continue to increase the opportunity cost of forest clearing. In order to achieve this goal, significant investments in education, training, and credit are still needed to help the rural population overcome "*entry barriers*" to such employment and creation of new business and public sector enterprises. Of course, the kinds of private sector businesses to be stimulated, perhaps through targeted credit, should not be predatory on the environment.

Nevertheless, we send a cautionary message to policy-makers regarding the expansion of public sector employment. Since it appears to offer among the best non-agricultural employment options in terms of job security, health insurance coverage, and wages, it is not surprising that it attracts an important share (33%) of the off-farm workers (mainly the better educated) in the sample. However, the supply of public jobs is closely associated with the country's economic growth (which has recently declined in Ecuador due to the fall in oil prices since 2014), so one wonders how sustainable the expansion of public sector jobs is in the medium term and what the effect of the on-going economic slowdown will be on natural resource use—an increase in depredation?

We conclude with a comment on the limitations of this study. The main limitation was that we worked with a cross-sectional data set, and thus were not able to test our hypotheses on a broader time frame. Therefore, a possible extension of this study would be to include the use of panel data in order to better determine the role of off-farm work on forest clearing and natural resource use.

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