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Elisa Meneghello, Martina Menon, Federico Perali and Furio Rosati

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THE SHADOW WAGE OF CHILD LABOR: AN APPLICATION TO NEPAL

ELISA MENEGHELLO, UNIVERSITY OF VERONA

MARTINA MENON, UNIVERSITY OF VERONA, Department of Economics, via Cantarane 24, Verona (Italy), Email: martina.menon@univr.it

FEDERICO PERALI, UNIVERSITY OF VERONA, ICID AND CHILD

FURIO ROSATI, UNIVERSITY OF ROME "TOR VERGATA", ICID AND CHILD

Abstract: This paper describes a new method to estimate shadow wages and to identify the shadow contribution of child labor. Our approach allows to perform a direct test for recursivity by comparing the estimated shadow wages with the market wage. This is a novel option to test for non-separability that adds to the traditional indirect tests based on restriction on production decisions or on consumption choices. Our innovative identification strategy is not specific to child labor but can also be used to identify the gender specific shadow wage of women and men. The estimated shadow wages, in the context of the Nepalese rural economy, are meaningful. Based on the evidence of our direct test for separability, we conclude that the separable representation of the farm households is not consistent with the Nepalese data. We further provide an estimate of the contribution of child labor to household income both at the household and national level. A set of simulations highlights the role that child labor plays in insuring household subsistence and how it affects Nepalese income distribution.

KEY WORDS: Shadow wage, child labor, effective labor, farm-household, separability, Nepal.

JEL CODES: Q12, J31, O12, D13, D11.

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1. Introduction

Most of child labor occurs in the agricultural sector, where children mainly work in the family farm. Returns to child labor are not directly observed in such a situation and need to be estimated. However, this has seldom be done if not through ad hoc assumptions or simplified approaches, which do not fully deal with the complexity of the issue (André *et al*. 2021). Information on returns to child labor are very important to assess the role played by children in the household and country economy, as well as for a correct design of intervention policies (Rosati 2022).

This paper describes a novel method to identify the shadow wage of child labor and estimates the contribution of child labor to the formation of household farm income in rural enterprises without unrealistically assuming the existence of well-functioning rural labor markets (Dillon and Barrett 2017, Dillon *et al*. 2019, Jones *et al*. 2020, LaFave and Thomas 2016, LaFave *et al*. 2020) and without assuming perfect substitutability between adult and child labor (André *et al*. 2021). We identify the shadow wage for each component of the household labor force by specifying a cost function with household labor as a quasi-fixed factor and deriving effective hours of adult and child labor using household technologies. This new method is not specific to child labor, but for instance it can be used to identify the shadow wage of women separately from that of men when family labor is employed in the household-owned business. The method is implemented in Nepal. The estimated shadow wages are meaningful and provide an estimate of the contribution of child labor to household income in the rural sector, both at the household and national level. A set of simulations highlight the role that child labor plays in insuring household subsistence and how it affects Nepalese income distribution.

The main identification issue of this research area is associated with the fact that most of the children do not work for a wage, but with their family, typically a farm or petty business. This makes it difficult to measure their contribution to family income also because researchers do not know who does what in the household business (The Wye Group 2015). Given the imperfection of the labor market, especially in agriculture, it is inappropriate to infer children's contribution to household income by using market wages that relate to adults because child labor employed outside the household is normally paid a wage that is often lower than the one prevailing on the formal market for adults and, for evident reasons, is not reported in the official labor statistics.

The recursive form of the household model is often inconsistent with both cross-sectional and panel data (Benjamin 1992, Dillon and Barrett 2017, Dillon *et al*. 2019, Jones *et al*. 2020, LaFave and Thomas 2016, LaFave *et al*. 2020), especially for less developed countries that often present imperfections in the labor and other factor markets, making the non-separability hypothesis more credible. When production and consumption decisions are non-separable, then market goods and leisure are not priced at the market value. The evaluation of labor is shadow and is revealed by the value of the marginal farm product.

To the best of our knowledge, very few systematic attempts have been made to fill this information gap by solving this identification problem. Researchers have mainly used extrapolation from children's wage equation, with the limitations discussed above or direct estimation of production functions normally applied only to estimates of the shadow wage of adult labor (Jacoby 1993, Skoufias 1994). In these studies, hired and family labor are both considered as variable factors valued at the same market price in the dual space. Therefore, the different marginal contribution to productivity, due for example to different levels of motivations and to managerial skills generally not required for hired labor, cannot be identified. Further, there is no acknowledgment that the productivity of adults and children as well as of male and female members of the household may not be the same.

Our estimation approach addresses two fundamental challenges: a) the presence of incomplete labor markets or the absence of formal labor markets in the case of child labor, and b) the identification problem due to the fact that adult and child labor are not perfect substitute. As household data do not allow to distinguish among the tasks performed within the household farm, we need to use information specific to adults and children to identify the marginal products of adult and child labor.

We deal with the empirically difficult issues (LaFave and Thomas 2016) by estimating the shadow value of family labor from the dual side modeling household labor as a quasi-fixed factor in the short run (Paris 1989). To obtain separate estimates of adult and child marginal product, we modify the shadow wages of family members to account for differences in adults' and children's characteristics using the notion of effective labor (Barten 1964, Brown 1983).

The paper makes three major methodological contributions. First, we estimate the shadow wage for family labor using a dual approach, which recognizes the quasi-fixed nature of family labor in the short run. If in the cost function we had treated family labor as a variable factor, an assumption commonly adopted in the literature, we would have assigned to family labor a market wage inconsistent with the evidence that production and consumption decisions are not separable. Our second contribution descends from the estimation of the shadow wage for family labor because it allows us to perform a direct test for recursivity by comparing the estimated shadow wage with the market wage. This is a novel option to test for non-separability that adds to the indirect tests based on restriction on production decisions (Benjamin 1992, Dillon and Barrett 2017, Dillon *et al.* 2019, LaFave and Thomas 2016) or on consumption choices (LaFave *et al.* 2020). Third, as an identification strategy for the shadow wage of children, we rely on information related to the skill endowment of either the adult or the child component of the family to infer their differential production quality (Barten 1964, Brown 1983, Perali 2003).

Within the context of the Nepalese economy, we further use the estimated value of the productivity of child labor to measure the contribution of child labor to the formation of household income in agricultural farms, where labor is evaluated at a shadow wage and estimates the size of children's shadow economy at the national level.

The paper is organized as follows. We first discuss the importance of child labor for the Nepalese farm-household economy and describe its main features. Section 3 introduces the farm-household model to be estimated. The strategy to identify shadow wages, the model specification and econometric technique adopted to deal with censoring in hired labor input are described in Section 4. Section 5 presents the main characteristics of the data set. In Section 6 we discuss the econometric results and estimates of the contribution of child labor to both household income and national product. The conclusions follow.

2. Child Labor in Nepal: Main Features

The empirical analysis is based on the Nepal 1996 LSMS survey.[1] The Nepal Living Standards Survey (NLSS) has been designed and managed by the World Bank. Data collection has been planned over a

[1] The research program foresees the extension of the technique that identifies the shadow wages of family labor to the more recent LSMS surveys for the years 2004-2005 and 2010-2011.

full year to cover a complete cycle of agricultural activities and capture seasonal variation in production variables, such as water availability. Field work took place in four subsequent phases starting in June 1995 and finishing in May 1996. The actual dataset numbers 3,373 households.[2]

It is unrealistic to assume that rural labor markets are competitive in Nepal. About 40 per cent of the Nepalese farm economy is subsistence agriculture isolated from both output and factor markets. About 81 per cent of Nepalese labor force is employed in the agricultural sector which accounts for about 40 per cent of GDP. Because of low investments, the level of human development is also low, limiting people's choices and capabilities. Child labor is mainly employed in agriculture, a sector that absorbs about 94% of the Nepalese total child labor employment (Sherin and Scott 2015, Datt and Uhe 2019). In Nepal, child work is concentrated mainly in self-employed agriculture and is more frequent in poor households. Poverty is a main factor determining child labor, affecting not just present but also future child status generations (Sam 2016). Basu and Van's (1998) luxury argument is not the only reason for employing a child in the farm or in the household (Deb and Rosati 2002, Rosati and Tzannatos 2006). Lack of off-farm job, especially in less developed countries, may generate expected off-farm wages that are lower than the return to labor employed with certainty on their own farm (Hill *et al.* 2007). Labor market imperfections (Dumas 2007) or inaccessible educational opportunities (Balhotra and Heady 2003), food insecurity and health status, also help explaining the high demand for child farm work. Child labor is also a consumption-smoothening strategy for poor households operating in risky environments and in regions where credit markets are missing or inefficient (Guarcello, Mealli and Rosati 2010) or in response to economic shocks (Koseleci and Rosati 2009). As maintained by Skyt Nielsen and Dubey (2002), the lack of parental human capital may explain high fertility rates making fewer resources available to enroll children in school.[3]

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[2] For more details on sample design, survey questionnaires, and field work see the Nepal Living Standards Survey (NLSS) - Survey Design and Implementation (1998 World Bank).

[3] In the NLSS survey, absence or distance to school are justifications adopted by less than 5 per cent of children 10-14 years old for not attending school. School cannot be afforded by 25.4 per cent of the sampled Nepalese

In general, substitution between child and adult labor implies that a child can do the same type of job as an adult, but not necessarily equally well (Basu and Van 1998, André *et al*. 2021). Nepal and Nepal (2012) find supports of the substitution between child and adult labor examining the relationship between adult illness and child labor: if adults get sick children work more. Bhukuth and Ballet (2006) state that for home-based enterprises children work is complementary to the work of adults. In this case, the informal employment of "unpaid" child labor is used to increase the household productivity.

In agriculture, child labor and adult labor may not be perfect substitutes. Children may produce lower quality goods or goods of similar quality but less efficiently either because of differences in strengths or skills and/or because are employed in different agricultural activities. Farm child labor might also be seasonal to accommodate schooling. Using the Nepalese micro-data our study shows that assuming a comparable productivity between adults and children, which also applies to differences in productivity between male and female components of the family, is not empirically tenable. Table 1 reports the geographical distribution and selected family characteristics for the whole Nepalese sample and for household without and with at least one working child 10-14 years old. The latter sub-sample is further divided in children self-employed in the household farms (Column c) and children employed in paid jobs (Column d). Child work is widespread in Nepal: about 40 per cent of the households with 10 to 14 years old children has at least one working child. By far the vast majority of these children is employed in the household farm (Column c).

Table 1 shows that the average household is headed by a 44.7 years old breadwinner and is composed of 6 members, 3 adults and 3 children (Column a). The household composition does not differ significantly across the sub-samples with and without working children. The level of education of the head of the household with non-working children is, though low, about twice as high as the level of education of households with working children (Column b). About 39 per cent of the households live in Central Nepal and more than half of the households are located in the hillside. About 52 per cent of the whole NLSS has at least a child 10-14 years old. In 69 per cent of the cases, there are children either

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households. This constraint seems especially stringent in households with girls (16.1 per cent of the total). In 19.4 per cent of the cases help at home was needed especially from girls (69 per cent).

working in agriculture (90 per cent) or in other paid job (10 per cent). Among the households with children self-employed in agriculture (Column c) and for households with children employed in other paid jobs (Column d) the average age of the head does not vary significantly. The average size of the household with children self-employed in agriculture (Column c) is 0.9 times bigger than the average size of households with children employed in other sectors (Column d). In the Terai region there are more off-farm opportunities as it can be deduced by the high proportion (0.51) of children not self-employed in agriculture. As expected, the annual consumption level of households with non-working children (Column b) is about 50 per cent higher than that of households with working children self-employed in agricultural (Column c).

Table 2 addresses the link between household consumption and child labor in Nepal. It shows the distribution of children's working hours by quintiles of household total consumption. In general, children belonging to the bottom two quintiles work more than children belonging to households relatively more well-off. Working children self-employed in agriculture work less than children employed in other sectors, except in the bottom quintile. This is mainly due to the seasonality of the agricultural activities.

Subsistence farming is widespread in Nepal involving about one third of the household whose main occupation is in agriculture (Table 3). As expected, households involved in subsistence farming are poorer, less educated, use more child work and have a slightly smaller family size with respect to other farmers. Subsistence farming is relatively more frequent in the Far-West and mountain regions of Nepal.

3. A Farm-Household Model with Child Labor and Associated Shadow Wages

We employ a traditional farm-household model to analyze the family decisions concerning child labor (Sen 1966, Rosenzweig 1980, Singh, Squire and Strauss 1986, Huffman 2001). We assume a unitary household, where decisions concerning children activity are taken by parents.[4] The parents distribute

[4]The unitary model is often empirically rejected when compared to collective models based on individual behavior (Chiappori 1992, Arias *et al.* 2003, Donni 2007, Matteazzi, Menon and Perali 2017, Chavas *et al*. 2018, Menon,

the income to the household members according to an undeclared sharing rule known to the household members but not directly observable by the researcher. We also consider the number of working age children as exogenous.

The household maximizes a strictly increasing and concave utility function W defined over a composite consumption good x_i and leisure l_i of both adults a and children c. Each household member has a total time endowment given by $T_i = l_i + L_i^I + L_i^O$, where L_i^I is on-farm labor, and L_i^O is off-farm labor. The strictly increasing and concave production technology F adopts two quasi-fixed but allocable inputs, adult L_a^I and child L_c^I family labor, and a variable input, adult hired labor L^H.[5] Technological uncertainty is modelled through the stochastic variable ϵ describing the random occurrence of agro-climatic shocks and other exogenous factors unknown to the researcher. Both the household welfare function W and the production technology F are assumed to be affected by a set of exogenous characteristics $\mathrm{d} = (d_a, d_c, d_f)$, pertaining either to the members of the household (d_a, d_c), such as parents and children age, gender and education, or to the farm d_f, such as the sharecropper status or the ownership of machinery.

The household expected welfare maximization program is

$$max_{x_a, l_a, L_a^I, x_c, l_c, L_c^I, L^H, q} E_\epsilon[W] = E_\epsilon\left[U\left(x_a, l_a, x_c, l_c; d_a, d_c, d_f\right)\right]$$

$$s.t.\ \sum_{i=a}^{c} x_i + \sum_{i=a}^{c} w_i l_i = \left[p_q q - \left(wL^H + \sum_{i=a}^{c} w_i L_i^I\right)\right] + \sum_{i=a}^{c} w_i T_i + y$$

$$q = F\left(L^H, L_a^I, L_c^I; d_a, d_c, d_f\right)\epsilon,$$

Perali and Piccoli 2018). However, the main interest in this study is the derivation of shadow wages of child labor rather than learning something about the child participation in the household decision-making process and the intra-household distribution of resources.

[5] For simplicity of notation, we are not considering here neither land as other non-labor inputs. These factors will be explicitly treated in the empirical model presented in Section 4.

$$\left(c_i, l_i, L_i^I, L_i^O, L^H\right) \in \wp, i = a, c,$$

where the expectation is taken with respect to the stochastic term ϵ. Farm output q is sold at the market price p_q.[6] The off-market labor L_i^O is supplied either in agriculture or other sectors at the market wage w. The off-farm wage is assumed to be different for adults and children, but equal across employment possibilities, either on other farms or in other sectors. All off-farm time uses have the same price. We assume that the market price of the composite goods, x_a and x_c, are equal across households and therefore are set to one. Looking at the right-hand side of the household opportunity set, the terms in brackets represent farm profits. The exogenous variable y measures non-labor income and $\wp$ is the constraint set limiting the choices of $\left(C_i, l_i, L_i^I, L_i^O, L^H\right) \in \wp, i = a, c$. The set can include positive constraints, or rationing factors because of particular market structures or other causes.

The corresponding Lagrangian function is

$$\mathcal{L} = U + \lambda\left[p_q F - \left(wL^H - \sum_{i=a}^{c} w_i L_i^I\right) + \sum_{i=a}^{c} w_i T_i + y - \sum_{i=a}^{c} x_i - \sum_{i=a}^{c} w_i l_i\right] + \mu_a L_a^O + \mu_c L_c^O,$$

where $\lambda \neq 0$ is the Lagrange multiplier associated with the budget constraint, and $\mu_a \neq 0$, $\mu_c \neq 0$ are the Lagrange multipliers associated with the inequality constraints related to the off-farm market labor choices of adults and children.[7] Maximization of the Lagrangian function with respect to the endogenous variables yields the following first order conditions

[6] Not all agricultural outputs are sold on the market, part of them are used for own consumption valued at a shadow price assumed to coincide with the market price. Interestingly, for family labor that does not participate in the labor market we estimate a reservation wage different from the market wage because of non-separability. The shadow wage of child labor, which cannot be observed on the market, is further differentiated from the shadow remuneration of adult labor using an identification strategy based on the Barten approach (Barten 1964) explained in Section 4.1.

[7] For reasons of space, we do not report the terms of both the utility function and the stochastic production technology in the Langrangian function.

$$\mathcal{L}_{x_i} = 0 \rightarrow U_{x_i} = \lambda,$$

$$\mathcal{L}_{l_i} = 0 \rightarrow U_{l_i} = \lambda w_i + \mu_i,$$

$$\mathcal{L}_{L_i^I} = 0 \ \rightarrow F_{L_i^I} = \frac{1}{p_q}\left(w_i + \frac{\mu_i}{\lambda}\right),$$

$$\mathcal{L}_{L^H} = 0 \rightarrow F_{L^H} = \frac{w}{p_q},$$

along with the derivatives with respect to the Lagrange multipliers.

Rearranging in terms of marginal rate of substitutions, the first order conditions become

$$\frac{U_{l_i}}{U_{x_i}} = w_i + \frac{\mu_i}{\lambda} = w_i^*, \tag{1}$$

$$\frac{F_{L_i^I}}{F_{L^H}} = \frac{w_i + \frac{\mu_i}{\lambda}}{w} = \frac{w_i^*}{w}, \tag{2}$$

for $i = a, c$. Equation (1) is the equilibrium condition for family utility maximization. The household equates the marginal rate of substitution between consumption and leisure of member *i* to her shadow wage. If member *i* works off-farm the corresponding complementary slackness condition μ_i is zero and the shadow wage w_i^* is equal to the respective market wage w_i. On the other hand, if member *i* does not supply her labor on the market, μ_i is greater than zero and her shadow wage in general will be greater than the respective market wage. In this case the model no longer presents the separability property between domestic production and consumption decisions (Matteazzi, Menon, and Perali 2017). The equilibrium condition for production maximization is given in Equation (2). The family-farm will hire adult labor up to the point where the marginal rate of transformation between family and hired labor is equal to the ratio between the family shadow wage and the wage paid to hired labor. The equilibrium conditions described in Equation (1) and (2) provide the structure for a direct test of separability. If we suppose that the marginal utility of consumption is $\lambda > 0$, and if the Lagrange multiplier associated with the off-farm market labor choices of either adults or children or both are different from zero, then the corresponding market and shadow evaluation of labor are not equal. This divergence is present only when consumption and production decisions are non-separable because both the consumption multiplier

λ and the production multipliers μ_i are different from zero. We empirically implement this test by estimating the shadow wage of family labor differentiated in adult and child labor using a dual approach that does not presume that the productivity of hired labor is equal to the productivity of family labor, thus forcing the production multipliers to zero.

When off-farm work and hired labor is zero, that is when such decisions are at a corner and family and hired labor are not perfect substitutes (Deolalikar and Vijverberg 1987, Jacoby 1993), labor is evaluated subjectively at its shadow wage. The choice not to work off-farm may be explained by objective causes such as missing labor markets or lack of contractual flexibility in the off-farm labor market. On the other hand, low subjective expectations about the probability of finding a job off-farm, especially for low-skilled workers such as children, may generate expected off-farm wages that are lower than a return to labor employed with certainty on the own farm. This observation is especially appropriate in Nepal where off-farm opportunities are lacking.

The production and consumption sides of the household economy illustrate the general equilibrium structure of the model. The exogenous characteristics d of the household and the enterprise affect both sides of the micro economy. Both household and farm characteristics are assumed to be predetermined before consumption and production decisions are made. Within the theory of the household enterprise this is an interesting feature because it allows testing the separability hypothesis between consumption and production decisions (Singh, Squire, and Strauss 1986, Benjamin 1992, Udry 1996). Under separability, the general equilibrium program of the household is recursive. Production decisions are not affected by household's endowments, preferences, characteristics or decision processes. On the other hand, consumption decisions are affected by production choices because profits are part of the budget constraint.

The separation between production and consumption decisions is ensured by the household rational behavior in presence of complete markets. The empirical works by Benjamin (1992), Udry (1996), Pavoni and Perali (2000), LaFave and Thomas (2016), Dillon and Barrett (2017), Matteazzi, Menon, and Perali (2017), Dillon *et al*. (2019), Jones *et al*. (2020) show that production decisions do depend on household preferences, characteristics, and endowments. Similarly, consumption decisions may depend on farms' characteristics. The simultaneity in decision making is evident even in the absence of market failures when the same input, such as time, is shared across the household and home production processes, and in presence of home consumption of the household marketable product. Imperfections in the labor, credit and land markets are commonly observed in empirical work. Under these conditions, farm production and household consumption decisions are non-separable and leisure/labor demand of the household is not independent from the on-farm demand of family labor. As a consequence, shadow wages, rather than market wages, determine adults and children's labor/leisure choices. The case of a Chayanovian farm-household closed economy (Sen 1966, Chayanov 1986, Pavoni and Perali 2000), which in Nepal is represented by subsistence farming, where the household members are not employed off-farm and no agricultural laborers are hired-in, is non recursive by construction (Lambert and Magnac 1994).

4. Identification Strategy, Econometric Specification and Estimation

The empirical estimates are based on a restricted cost function with three allocable quasi-fixed factors: 1) adult labor, 2) child labor, and 3) land and capital. By specifying on-farm labor L_a^I and L_c^I as quasi-fixed factors, it is not necessary to impute a market wage for L_a^I and L_c^I in the opportunity set $\wp$. We can estimate it as the shadow wage corresponding to the value of the marginal product. By separating hired and family labor, we need to model a censoring process on the input side because only 2.6 per cent of the farms in the sample hire labor. The econometric specification then pays special attention to the modeling of a) market imperfections, and b) skill differences between adults and children.[8]

4.1 Identification Strategy

Objective market wages w and subjective shadow wages derived in Equation (1) differ if markets are incomplete so that the agricultural household model is non-separable. The case of child work is a case

[8] We choose to model the production technology without accounting for the stochastic nature of agricultural production, the riskiness of input markets and uncertainty about future prices also considering that linkages to markets in Nepalese agriculture are weak because markets are often missing in remote rural areas or otherwise incomplete and non-competitive.

of non-separability due to a labor market failure. Further, child labor, as is likely for female labor, are inter-locked factors because employed both in production and consumption decisions. If recursivity holds, the influence of demographic variables, clearly important in consumption decisions of market, non-market goods and leisure should not have a significant impact on production choices (Benjamin 1992, LaFave and Thomas 2016, Dillon and Barrett 2017, Dillon *et al*. 2019) or consumption choices (LaFave *et al*. 2020). Another factor contributing to the improper functioning of local labor markets is that family labor can be considered fixed in the short run. The cost function provides a natural set up to model both the non-separability of the production and consumption decisions within a farm household and the fixed provision of family labor. It suffices to introduce adult and child family labor as fixed translating terms and to derive the associated shadow wages as the derivative of the total cost function with respect to the fixed factor. The primal approach pursued by Jacoby (1993) and Skoufias (1994) suffers from an internal inconsistency. The dual of the production technology, where hired and family labor are assumed to be variable factors, is a cost function whose arguments are the market wages for both hired and family labor, thus presuming separability. If we estimate shadow wages from the primal side, the value of the marginal product of hired labor would be the same as for family labor. The corresponding cost function would then be specified implying separability, which is a clear inconsistency.

When child's work is not a perfect substitute for the work of an adult and/or children do not perform the same activities as the adults, then the marginal productivity is different both because adults and children have different skills and because they are allocated to different activities according to a natural division of labor (Becker 1965). In general, heavy activities, such as ploughing, are naturally undertaken by adults, while picking or other less demanding activities, such as grazing animals, are parts of children's jobs. Because of the questionnaire design, we do not know "who does what" in the field either for the adults or for the children. As a consequence, it is impossible to differentiate the productivity associated with each task. Because of this informational constraint, in our framework both adult and child labor are modeled as quasi-fixed factors which affect only the joint product.

Given this informational constraint, we are bound to assume that adults and children produce the same product with different levels of quality/quantity per unit of time, which, in turn, are associated with age (adult/child) specific shadow wages. This relationship can be modeled with *a la* Barten (1964) specifications relating differences in the quality/quantity of a product with the hedonic characteristics of the worker (Brown 1983, Benjamin 1992). This is a reasonable assumption if the agricultural wage of interest is the implicit shadow wage paid to family labor that is not observable.

To accommodate these features in the econometric analysis, we extend the traditional estimation of production technologies by formally accounting for the facts that a) the farm-household economy is non-separable; b) adult and child family labor are quasi-fixed factors in the short run; and c) adults and children are not perfect substitutes.

If we do not account for quality differences of the product obtained from adult and child labor due to heterogeneity in their skills, the shadow wage w_i^*, corresponding to the value of the marginal product, is the same for both adults and children. It will differ, however, from the market wage w prevailing in the agricultural sector

$$w_i^* = \frac{\partial q}{\partial L_a} p_q = \frac{\partial q}{\partial L_c} p_q \neq w,$$

where p_q is the market price of the aggregated output q.

In order to differentiate adult from child labor, effective family labor is modeled as a modified factor $L_i^{I*} = L_i^I \theta_i(d_i)$, for $i = a, c$, where d_i describes the set of individual specific characteristics affecting the Barten (1964) scaling modifying function $\theta_i(d_i)$.[9] The scaling function $\theta_i(d_i)$ can be interpreted as a quality correction factor reflecting the fact that children with different characteristics may perform their tasks with significantly different levels of quality.

The scaling transformation leads to the following definition of the effective wage

$$w_i^* = \left(\frac{\partial q}{\partial L_i} \theta_i(d_i)\right) p_q \neq \frac{\partial q}{\partial L_i} p_q \text{ for } i = a, c. \qquad (3)$$

The scaling function $\theta_i(d_i)$ also generates the shadow effective wage w_i^{*e}

[9] See also Yotopoulos and Lau (1973), Benjamin (1992), Kumbhakar and Knox-Lovell (2000) in more recent production applications.

$$w_i^{*e} = \frac{w_i^*}{\theta_i(d_i)},$$

by attributing differences in shadow wages to "hedonic" differences in worker characteristics (Brown 1983).

The implementation of the dual side of the above program, with an explicit treatment of family labor and land as quasi-fixed but allocable factors, requires the definition of a modified (*a la* Barten in our case) restricted short-run cost function which can be written as

$$c(q, w; z, d) = \min\{wr + w^* z \mid q = F(r; , z, ; d)\},$$

where w is an *r*-vector of input market prices and r is an $r = \{1,2,3\}$ vector of variable inputs (hired labor, chemicals, materials), z is a $g = \{1,2,3\}$ vector of the quasi-fixed factors farm adult labor, farm child labor, the value of land and capital assets, q is an $i = \{1,2,3,4\}$ vector of predetermined levels of outputs (cereals and vegetables, fruit, milk, livestock), d is a $k$vector of exogenous characteristics of the farm-workers, F is the production technology, and w^* is as defined in Equation (3). The structure of the minimization problem imply that the cost function is homogeneous of degree one in input and output prices. Two additional properties of the cost function are of interest for estimation purposes. First, by Shephard's lemma we have that

$$r_i(q, w; z, d) = \frac{\partial c(q, w; z, d)}{\partial w_i},$$

where r_i is the *i*-th component of the input vector and w_i is the price of that input. These input demand functions are homogeneous of degree zero in input prices. Second, if entrepreneurs are minimizing costs, we obtain the quasi-fixed factor's shadow wage

$$w_i^* = \frac{\partial q}{\partial z} p = \frac{\partial c(q, w; z, d)}{\partial z} = \left(\frac{\partial c}{\partial z} \theta(d)\right) p,$$

by differentiating total costs with respect to the level of the quasi-fixed factor (Paris1989). This is the behavioral basis of our modeling strategy.

4.2 Econometric Specification

We estimate a system composed by a restricted translog cost function with four outputs, three inputs modified with a translating function to accommodate three-quasi fixed factors and its derivatives with respect to input prices. Quasi-fixed inputs act as exogenous factors modifying the cost function via shifting. The translog total cost function modified via a translating transformation (Pollak and Wales 1981, Lewbel 1985) can be written as

$$\ln c(q,w;z,d) = \alpha_0 + \sum_{i=1}^{4} \alpha_i \ln q_i + \sum_{r=1}^{3} \beta_r \ln w_r + \sum_{g=1}^{2} \gamma_g \ln(z_g \theta_g(d)) + \gamma_{\mathrm{g=3}} \ln z_{\mathrm{g=3}}$$

$$+ 0.5 \sum_{i=1}^{4} \sum_{j=1}^{4} \alpha_{ij} \ln q_i \ln q_j + 0.5 \sum_{r=1}^{3} \sum_{s=1}^{3} \beta_{rs} \ln w_r \ln w_s$$

$$+ \sum_{r=1}^{3} \sum_{i=1}^{4} \gamma_{ri} \ln w_r \ln q_i + \sum_{r=1}^{3} \sum_{k=1}^{5} \varsigma_{rk} \ln w_r \ln d_k, \quad (4)$$

where w_r is the market price of input r.

The scaling demographic function

$$\theta_g(d) = \exp\left(\sum_{j=1}^{3} \delta_j \, d_j \right) \quad (5)$$

is specified as linear in the logarithm function of the exogenous characteristics d. The set of demographic characteristics transforming adult work includes the gender of the household's head, the types of the consumed goods considering if they are produced within or outside the family, and the level of technology that is used to cultivate the plots. On the other hand, the set of children's characteristics includes the number of students in the family, the average age of child family members and the consumption score indicating increasing adequacy of consumption for values higher than 12.

Using Shephard's lemma, the derivatives of the cost function with respect to the logarithm of input prices can be written as

$$s_r = \beta_r + \sum_{s=1}^{3} \beta_{rs} \ln w_s + \sum_{i=1}^{4} \gamma_{ri} \ln q_i + \sum_{k=1}^{5} \varsigma_{rk} \ln d_k,$$

where $s_r = -\frac{w'x}{c} = -\partial \ln c / \partial \ln w$ is the cost share of the r-th input. Homogeneity of degree one in$w$ of the cost function implies the following parametric restrictions

$$\sum_{r=1}^{3} \beta_r = 1, \sum_{r=1}^{3} \gamma_{ri} = \sum_{r=1}^{3} \beta_{rs} = \sum_{r=1}^{3} \varsigma_{rk} = 0,$$

and symmetry

$$\alpha_{ij} = \alpha_{ji}, \beta_{rs} = \beta_{sr}.$$

In general, the properties derived from the optimization structure of the model can be tested. In the present case, linear homogeneity in prices and symmetry are imposed as maintained hypothesis. Considering total farm costs as obtained by the sum of the short run costs to the imputed costs of the quasi-fixed inputs, it is possible to evaluate the shadow wage of on farm labor. The shadow wage is derived as the marginal effect of a long-run change in fixed factors on total costs

$$w_z^* = \frac{\partial c(q,w;z,d)}{\partial z_g} = \frac{\partial \ln c(q,w;z,d)}{\partial \ln z_g}\frac{c}{z_g} = \gamma_g \frac{c}{z_g}, \tag{6}$$

where c and z_g are total costs and adult or child working hours respectively.

The effect of demographic characteristics on total costs correspond to the following partial contribution

$$\frac{\partial c}{\partial d_j} = \frac{\partial \ln c(q,w;z,d)}{\partial d_j}\, c = (\gamma_g \delta_j)c,$$

which allows to derive the effective shadow wage of adult and child labor

$$w_z^{*e} = w_z^* + \frac{\partial c}{\partial d_j}$$

given by the sum of the shadow wage w_z^* to the marginal productivity of labor provided by the characteristics of the worker.

4.3 Econometric Estimation

One of the main problems encountered in the estimation of the shadow wages for the Nepalese agricultural sector is the modeling of multiple-output production technologies and of zero realizations because not all farms produce all outputs using all inputs. We deal with this censoring problem by adopting an extension of the Heckman model to estimate a system of equations with censored variables.

To deal with the censoring in the input equation for hired labor, we make use of the Generalized Heckman approach which extends the Heckman two-step estimator extended to a system of censored equations. This method gives unbiased estimates as compared to the maximum simulated likelihood method (Hajivassiliou, McFadden, and Ruud 1996) using simulated multiple integrals to reproduce the statistical process that generated the zero realizations (Arias and Perali 2003).[10]

Our approach assumes that the zero realizations are the outcome of a rational economic choice or that they are determined by physical, technological, or normative constraints. This justifies a Tobit structure. The data generating process that we assume reproduces the unconstrained choice of not undertaking a certain activity if the output price is below a reservation price corresponding to a break-even point. In a general representation of a system of equations with censored endogenous variables, each equation in the system can be written as

$$y_i = f_i(x_i, \beta_i) + u_i \; iff_i(x_i, \beta_i) + u_i > 0,$$

$$y_i = 0 \; iff_i(x_i, \beta_i) + u_i < 0, \tag{6}$$

where y_i is the endogenous variable corresponding to the i-th equation in the system, x_i is a vector of explanatory variables, β_i is a vector of parameters and u_i is a random variable. Precisely, u_i is the i-th component of a multivariate normal random vector u of mean zero and variance $\sum$. Therefore $u_i \sim N(0, \sigma_i^2)$, where σ_i^2 is the i-th diagonal term of the matrix $\sum$.

The Generalized Heckman procedure transforms the system of censored equations in (5) into a system of uncensored equations by using the appropriate correction. We start by considering the expected value of the endogenous variable conditional on a positive observation

$$E[y_i|y_i > 0] = f_i(x_i, \beta_i) + \sigma_i \frac{\phi(f_i(x_i, \beta_i)\sigma_i)}{\Phi(f_i(x_i, \beta_i)\sigma_i)},$$

where ϕ and Φ are respectively the probability density function and the cumulative density function of a standard normal distribution. Then, the unconditional mean (conditional only on explanatory variables) is

$$E[y_i|x_i] = f_i(x_i, \beta_i)\,\Phi\left(\frac{f_i(x_i, \beta_i)}{\sigma_i}\right) + \sigma_i \phi\left(\frac{f_i(x_i, \beta_i)}{\sigma_i}\right).$$

Using the expression for the unconditional expected value of each endogenous variable we consider the

[10] In the simulated maximum likelihood approach the variance covariance matrix of the parameters is a full matrix, while in the generalized Heckman estimator only the diagonal terms can be estimated.

following system of uncensored equations

$$y_i = f_i(x_i, \beta_i)\Phi\left(\frac{f_i(x_i, \beta_i)}{\sigma_i}\right) + \sigma_i \phi\left(\frac{f_i(x_i, \beta_i)}{\sigma_i}\right) + \xi_i,$$

where $\xi_i = y_i - E[y_i|x_i]$ and ξ_i is the i-th element of a random vector ξ. To deal with the presence of endogeneity in input quasi-fixed factors the control function approach has been used, combining the use of external and Lewbel's generated instruments as exposed in the Appendix.

5. Data

The empirical analysis is based on the Nepal Living Standard Survey 1996.[11] The estimation has been carried out on a sample of 2,380 farm households obtained excluding observations relative to singles (2.16 per cent), landless households (23 per cent), non-farming households (3.44 per cent), those farming households without adults self-employed in agriculture (0.56 per cent), and households with head younger than 17 years old (0.15 per cent).

Table 4 shows the descriptive statistics of the farm household sample used in the estimation along with standard deviation, minimum and maximum values. The table also reports the definitions of the variables and the unit of measurement. In the presence of sharecropping contracts, which are found in 18 per cent of the sample, and for subsistence farms, representing 33 per cent of the cases (Table 4), prices are not observed and have been imputed using *ad hoc* techniques. This measurement aspect is crucial because without output prices the implicit valuation of labor corresponding to the value of the farm marginal product cannot be derived.

[11] The NLSS survey is made up of the following eleven sections: 1) Socio-demographic information such as age, education, paid working hours, and wages; 2) Family and children 10-14 years old paid working hours and family wages; 3) Health information at the household level of aggregation; 4) Farming and livestock; 5) Production, sales and prices of agricultural activities; 6) Expenditure on agricultural inputs; 7) Credit and savings; 8) Remittance and transfers, plus other income; 9) Household consumption and expenditure; 10) Geographic location of the household. For the purpose of estimating the shadow wage of child labor it is relevant to report that the data do not include information on the specific tasks carried out in the farm by each household member.

Total costs have been computed as the sum of variable and fixed costs including adult and child labor and the use value of land and capital assets. In particular, family labor is evaluated as the accounting value left after having paid all other factors of production and value of fixed assets is computed as the 1 per cent of the overall value of land and capital. Output prices of subsistence farms have been imputed with the prevailing average price in the observed location of the farm. Note that when fixed costs are included, then by construction total costs equal total revenues (TR) because the accounting value of fixed costs is computed assuming a long run perspective. Total fixed costs (TFC) are composed by the opportunity cost of the money invested in the fixed plant R and the fixed costs associated with fixed labor. The return to family labor (RFL) is defined as $RFL = TR - TVC - R$, where TVC are total variable costs. Given this accounting construction, profits are zero and total costs equal total revenues. We assume that when $RFL > 0$, then the returns to family labor are sufficient to keep a family farming in the long run.

The farm characteristics included in the analysis are the regional dummies distinguishing the Eastern and Central regions from the other regions of Nepal and the Terai planes. The dummies for sharecropping and subsistence farming, a farm status predetermined with respect to the timing of production decisions, are intended to capture some crucial structural and institutional characteristics of the Nepalese farming mode. The estimates consider the presence of endogeneity in adult on-farm labor, implementing a 2SRI approach using both external and generated instruments as illustrated in detail in the Appendix, which provides unbiased and consistent estimates (Terza, Basu and Rathouz 2008) using both the selected external instruments and the generated ones.

6. Results

The estimates of the modified translog cost function obtained using a maximum likelihood procedure are presented in Table 5. The proportion of significance of the parameters is homogenous across the group of prices, outputs (cereals and vegetables, fruit, milk, livestock) and demographic characteristics.

In the case of a translog cost function specification, analyzing the Allen elasticity matrix corresponds to analyze the Hessian matrix of the translog cost function of the second derivatives with respect to prices, to check for the curvature (Perali 2000, Christev and Featherstone 2009). The Allen elasticities of substitution for the three variable inputs, hired labor, chemicals and materials, reported in Table 6 show the correct sign along the diagonal. This evidence says that at the data means the curvature of the cost function is regular. The own impact of hired labor is highly elastic. The inputs are all substitutes. The marginal effects of farm characteristics and fixed factors on total farm costs are presented in Table 7. In the Eastern regions of Nepal and in subsistence farming, where the agricultural product is not sold on the market, costs are relatively higher. Costs are lower where sharecropping is the mode of agricultural production, in Terai plans and in central Nepal. In the case of sharecropping the marginal evaluation of labor is based on the value of total production farmed not just on the proportion of production sold on the market after having paid the rent to the landlord. Similarly, the shadow wage of workers producing in subsistence farms is evaluated at an imputed price. The coefficients associated with the fixed factors are the marginal effect on total costs. The coefficient then provides a direct evaluation of the shadow wage as illustrated in Equation (4). As expected, the effect of adult and child labor is positive and significantly different from zero.

The estimated adults' and children's shadow wages are presented in Table 8. The shadow wages are evaluated 1) at the unconditional mean of all the variables, $E(w_i^*)$, 2) conditional on positive levels of child labor, $E(w_i^*|z_2 > 0)$, 3) conditional on absence of child labor but in presence of children 10-14, $E(w_i^*|z_2 = 0 \,\&\, \text{nchild1014} > 0)$. In addition the three shadow wages as previously defined are also evaluated conditional on subsistence status (i.e. $E(w_i^*|Subsist = 1)$, $E(w_i^*|z_2 > 0 \,\&\, Subsist = 1)$ and $E(w_i^*|z_2 = 0 \,\&\, nchld1014 > 0 \,\&\, subsist = 1)$).

When child labor is present, the adult and child wage differential is about 0.304 rupees per hour

$$w_a^* - w_c^* = 1.186 - 0.882 = 0.304,$$

corresponding to a child-adult wage ratio of $w_c^*/w_a^* = 0.744$. The shadow value of the child productivity is more than a half of the adult at the data mean. This result shows that adult and child labor are not perfect substitutes (Basu 1999 and 2000).

Adult and child shadow wages estimated using the dual approach fit the Nepalese shadow economy closely. Comparison of the estimated shadow wages with the market wage of a hired worker, which we have calculated to be of 1.86 rupees per hour,[12] provides the evidence for directly testing the separability hypothesis. For example, when there are working children, the estimated shadow wage is lower than the market wage (Table 8, Column b). Further, the shadow wage for subsistence farming does not significantly differ from the market wage (Table 8, Column d). We may then conclude that the separable representation of the Nepalese farm households is not consistent with the data.

With the contribution of child labor, the total household wage sums up to 2.068 rupees per hour. Families with such a low-income experience severe poverty and may feel strongly pressured to send children to work. However, we may also consider the possibility that households employ children because of lack of alternatives in the use of their time (school not present, school costs to high, or low return to education), which may generate a situation of "over-employment" that reduces productivity.

When children are not working but are present in the household, the value of the adult productivity is 3.613 rupees per hour (Table 8, Column c). Assuming that an adult family member works on average 8 daily hours per 288 days in a year, or equivalently 2,304 hours in a year, the annual contribution to the household income is 2,732.54 rupees in the presence of working children that is under the per capita poverty line. Instead, when there are children who are not working, the annual contribution to the household income is 8,324.35 rupees that is above the poverty line.

Conditional on a situation of subsistence, the adult and child wage differential is 0.430 rupees per hour, $w_a^* - w_c^* = 0.937 - 0.507 = 0.430$, corresponding to a child-adult wage ratio of $w_c^*/w_a^* = 0.541$. In this situation, the shadow value of child productivity is about a half of the adult at the data mean. When there are working children, the adult shadow wage is 0.937 rupees per hour (Table 8, Column e). When children are present in the household but they're not working, the value of the adult productivity is 3.191 rupees per hour (Table 8, Column f). Under subsistence conditions, and

[12] In our sample only 2.6 per cent of farms hire permanent workers. On average, these farms hire less than two full-time workers (1.45) and the cost for each worker is about 4,292 rupees per year. Note that a permanent hired worker earns an amount of money slightly lower than the estimated poverty line, 4,404 rupees (Prennushi 1999). If each employee works on average 2,304 hours a year, then the wage for hired labor is 1.863 rupees per hour. Note that in 1997 one US $ corresponds to 63 Nepali rupees.

maintaining the assumption that an adult family member works 2,304 hours in a year, the annual contribution of an adult to the household income in presence of working children falls lower, and it is about 2,158.85 rupees, which is less than half the poverty line. Instead, the annual contribution of an adult to household income in presence of non-working children is above the poverty line (7,352.06 rupees). Results underline the fact that under any condition of the household, children are occupied in farm-household work when their involvement is more demanded.

It is important to remark that the degree of adult/child substitutability is affected by differences in characteristics. For example, an educated child going to school may be a better substitute for the labor performed by an adult with a low level of education. Therefore, a proper comparison between shadow wages should take into consideration differences in the effectiveness in performing the work, as it can be deduced from the different characteristics of adult and child labor employed in the farm. Considering not just the difference in productivity between adults and children, but also the households' characteristics that may affect productivity, improves the goodness of fit of the econometric model.

Table 9 shows that the use of technology in agricultural activities has a positive impact on the productivity of the adults. The effective shadow wage of farmers with a male head, with high level of household consumption of home products, and adopting a higher level of farming technology is significantly larger. Effective shadow wages for children are positively influenced by high level of adequacy of consumption. As it is reasonable to expect, children's productivity is lower when consumption levels are inadequate and precarious health conditions affect their performance. On the other hand, effective shadow wages are negatively influenced by the presence of students.[13]

From these estimates, we may conclude that the child marginal contribution to the shadow farm economy in Nepal is about three fourths of the contribution of the adult, and about one half under

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[13] We also test the degree of homogeneity of the demographic modifying function $\theta_g(d) = \sum_{j=1}^{3} \delta_j d_j$ as in Dickens *et al.* (1993) and Perali (2003). Homogeneity of degree zero in demographic characteristic d implies that coefficients of the scaling function must satisfy the following constraint $\sum_{j=1}^{3} \delta_j = 0 \; \forall g = a, c$. An F-test of the unrestricted model accepts the null hypothesis on the parameters restriction both for adults' and children's on-farm labor. This evidence is also supported by likelihood ratio tests available from the authors upon request.

subsistence conditions. Considering that children in Nepal provide 17.6 per cent of rural labor, in terms of annual working hours, we may attribute to children a contribution of 13.09 per cent of the value of Nepalese agricultural production and of 9.52 per cent under subsistence conditions.

This represents a substantial contribution to agricultural production in Nepal and clearly illustrates the important role that child labor plays in the Nepalese economy. It is also very important to assess whether and to what extent child labor does help poor households to meet their subsistence needs. If the role of child labor in guaranteeing the subsistence of the household were negligible, then policy actions should be focused on reducing the direct and indirect costs of accessing education, on improving returns to education, on raising awareness of the importance of education. Less attention should be paid to the returns to child labor and to the need to compensate the household for forgone income.

In order to gauge whether the presence of a working child has a significant impact both on the level of poverty and inequality, we simulate the distribution of household income for the households with working children as if children were not contributing the value of their labor. We then compare the associated measures of poverty and inequality with the measures for the whole sample and the households with and without working children. Table 10 shows the headcount, poverty gap, the Foster, Greer and Thorbecke indexes and standard measures of dispersions along with the Gini coefficient for the whole sample and the subgroups of interest. Farming households with working children (Table 10) have higher levels of poverty both in terms of number of households below the poverty line and in terms of depth and severity of poverty. These figures would be substantially higher if the children were not working. If the contribution of child labor is subtracted from household income, there is an increase of 7 percentage points in the number of households below the poverty line. The headcount ratio increases from 53 to 68 per cent. Child work contributes to keep a large number of households above the poverty line. The fact that the poverty gap ratio also increases significantly when we assume children were not working suggests that child labor is vital for very poor households. The absence of the additional source of revenues provided by the children may push those households well below subsistence. This is also reflected in the increase in the Sen and FGT index in the simulated case. The difference in the impact on inequality for the actual and simulated situation, as described by standard measures of dispersion and the Gini coefficient, is negligible.

7. Conclusions

This work estimates the shadow and effective shadow wages of children in Nepal. The identification strategy differs from the previous literature (Jacoby 1993, Skoufias 1994) because it adopts a dual approach and a Barten-type household technology, which is necessary to differentiate child labor from adult one. This approach is pursued because the primal representation of the technology does not allow treating fixed and variable factors differently. Normally rural labor markets are assumed to be perfect and fixed factors are evaluated implicitly at their market value rather than at their implicit shadow value. Shadow prices are appropriate when farm and household decisions are non-separable, which should be the case where agricultural labor and other factor markets often fail or are missing as in Nepal.

The estimation of shadow wages for family labor is then carried out using a cost function rather than a production function. Based on the evidence of a direct test for separability, which compares estimated shadow wages with the market wage, we conclude that the separable representation of the Nepalese farm households is not consistent with the data.

Shadow wages specific to adults and children are inferred modeling observable heterogeneity about the different characteristics of adults and children that may affect productivity. The present study is the first application adopting household technologies to identify the productivity of child labor.

The estimated child shadow wage is, at the mean, about 75 per cent of the adult shadow contribution. This conclusion may not be generalized. For example, in terms of the effective shadow wage obtained by a child with inadequate consumption, the degree of substitutability is significantly lower. According to these results, children contribute about 13.09 per cent of the value of total agricultural production in Nepal. Considering that agriculture is responsible for 81 per cent of Nepalese GDP at least 10.60 per cent of Nepalese GDP is produced by children. The simulation about the impact on poverty and inequality associated with the children pooling or not their income shows that children significantly contribute to lower poverty at the household level and, at a lesser extent, to reduce inequality.

From a policy point of view, it is important to ask how much of the value of the output produced by children remains under their control. When children offer their time outside the household enterprise, then they may maintain full, partial or no ownership of their incomes. On the other hand, in the case that children are employed on-farm, the value of the child product is managed by the adults, who are the final claimants and responsible for the redistribution of income within the household. This question can find an answer at the household level if we can measure how the resources produced by the children from their work on the farm are redistributed within the household. The investigation of this issue, which requires a collective approach to the modelling of the farm household, is going to be the object of our future research.

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Table 1. Demographic Characteristics of the Nepal Living Standard Survey (NLSS)

	NLSS	Households with at least a child 10-14 years old		
		With non-working children	With non-working children	
			Self-employed in agric.	Not self-employed in agric.
	(a)	(b)	(c)	(d)
No. of observations	3,373	1,032	642	72
Eastern	0.213	0.234	0.181	0.181
Central	0.391	0.370	0.347	0.403
Western	0.185	0.231	0.115	0.208
Mid-West	0.107	0.090	0.181	0.083
Far-West	0.104	0.076	0.176	0.125
Mountain	0.121	0.074	0.188	0.042
Hill	0.516	0.571	0.379	0.444
Terai	0.363	0.356	0.433	0.514
Head's education	1.914	3.102	0.643	2.319
Head's age	44.70	45.47	45.18	42.24
No. of adults	3.220	3.354	3.358	2.806
No. of children 10-14	0.753	1.408	1.523	1.528
No. of children 0-18	2.757	3.505	4.040	3.667
Family size	5.977	6.859	7.399	6.472
Total consumption[a]	49,053	61,789	37,434	53,579

Notes: [a] Annual household total consumption is in rupees.

Table 2. Average Children's Annual Working Hours by Quintile of Household Total Consumption and by Working Sector

Quintile	NLSS	With working children	
		Self-employed in agric.	Not self-employed in agric.
No. of observation	3,373	642	72
1st	242	1,311	1,183
2nd	403	1,386	1,666
3rd	284	1,164	1,376
4th	239	1,104	1,196
5th	112	812	1,095

Table 3. Demographic Characteristics of Subsistence and Non-subsistence Farm Households

Variable	Farm Households	Non-Subsistence	Subsistence	
			without working children	with working children
No. of observations	2,380	1,600	615	165
		Farm Characteristics		
Total costs[a]	30,668	37,003	18,649	14,032
Total hectares	0.983	1.123	0.666	0.819
Adult annual working hours	3,428	3,637	2,802	3,736
Child annual working hours[b]	1,135	1,064	0	1,317
Sharecropping	0.181	0.211	0.112	0.145
Subsistence	0.328	-	-	-
		Geographical Location		
Eastern	0.216	0.246	0.154	0.152
Central	0.316	0.339	0.276	0.236
Western	0.207	0.193	0.263	0.139
Mid-West	0.129	0.134	0.104	0.176
Far-West	0.133	0.089	0.202	0.297
Mountain	0.153	0.133	0.167	0.303
Hill	0.492	0.466	0.567	0.461
Terai	0.355	0.402	0.265	0.236
		Family Characteristics		
Head's education	1.351	1.622	1.003	0.024
Head's age	45.14	45.50	44.32	44.62
No. of adults	3.366	3.443	3.218	3.170
No. of children 0-18	2.278	2.306	1.961	3.194
No. of children 10-14	0.807	0.840	0.540	1.479
Family size	6.397	6.558	5.807	7.042
Total consumption[a]	39,242	41,118	36,094	32,783

Notes: [a] Total costs and annual household total consumption are in rupees. [b] We report the mean conditional on farm households with positive child labor.

Table 4. Summary Statistics of the Farm Household Sample Used in the Estimation of the Modified Translog Total Cost Function and Input Shares. No. of Observations 2,380

Variable	Definition of Variables	Mean	Std. Dev.	Min	Max
ln c	log of total costs	9.574	1.078	5.897	14.638
ln q_1	log of cereals and vegetables output	3.980	1.574	0	12.631
ln q_2	log of fruit output	1.020	1.976	0	10.602
ln q_3	log of milk output	1.026	2.086	0	11.590
ln q_4	log of livestock output	0.684	1.452	0	10.491
s_1[a]	hired labor input share	0.138	0.23	0	0.985
s_2	chemicals input share	0.304	0.263	0.002	0.996
s_3	materials and other input share	0.558	0.324	0.002	0.997
ln w_1	log of hired labor wage	3.808	2.918	−1.553	8.001
ln w_2	log of chemicals price	2.259	0.524	0.584	5.299
ln w_3	log of materials price	6.652	1.372	1.099	12.357
z_1	log of adults' on-farm working hours	7.758	1.046	0	10.543
z_2[b]	log of children's on-farm working hours	1.510	2.856	0	9.072
z_3	log of average of land and capital costs	−0.963	1.287	−5.942	4.118
d_1: Terai	dummy: 1 if live in Terai	0.355		0	1
d_2: Eastern	dummy: 1 if live in east Nepal	0.216		0	1
d_3: Central	dummy: 1 if live in centre Nepal	0.316		0	1
d_4: Sharecropping	dummy: 1 if sharecropping contract	0.181		0	1
d_5: Subsist	dummy: 1 if subsistence agriculture	0.328		0	1
d_6: Head_sex	Dummy=1 if female head	0.116		0	1
d_7: Home_produc[e]	dummy: 1 if food is mainly own-produced	0.661		0	1
d_8: Tech[d]	Level of technology	1.158	0.706	0	2
d_9: Students[e]	Number of students in the family (classes)	1.949	0.826	1	3
d_{10}: Child_age[f]	Children's age category	1.960	0.883	0	3
d_{11}: Cons_Score[g]	Consumption Score classes	0.943	0.438	0	2

Notes: All variables refer to the twelve-month period foregoing the date of interview. Due to the presence of zero values in some inputs and in children's on-farm working hours, the logarithm transformation has been applied by adding one to all input levels and to the level of z_2. [a] 36.97 per cent of the sample employs hired labor either casual or permanent. [b] 24.70 per cent of the sample employs child labor on the farm. [c] Home_produc is equal to 1 if more than 50 per cent of family food consumption is self-produced within the household. [d] Tech is equal to 0 when no technology is owned, 1 when a low technology is owned and 2 when a high technology is owned. [e] Number of students in categories: 1 if there are no students in the family, 2 if there are 1 and 2 students, and 3 if there are 3 or more students.[f] Children's age categories: 0 if there are no children, 1 if younger than 5 years old, 2 if between 5 and 9 years old, 3 if 10 years old or more.[g] Consumption Score classes are: 0 if score is less than 6, 0.5 if score is equal to 6, 1 if score is between 6 and 9, 2 if score is between 10 and 13, and 3 if score is greater than 13 (lower values refer to greater inadequacy of consumption and higher values refers to adequacy of consumption).

Table 5. Estimates of the Modified Translog Total Cost Function with Three Inputs and Three Quasi-Fixed Factors with External and Generated Instruments for Endogeneity of Adult Farm Labor

Parameter	Coefficient		S.E.	Parameter	Coefficient		S.E.
α_0 intercept	3.261	***	0.3032	γ_{21} ln w_2 ln q_1	0.015	***	0.0033
α_1 ln q_1	0.326	***	0.0820	γ_{22} ln w_2 ln q_2	0.007	***	0.0024
α_2 ln q_2	0.307	***	0.0442	γ_{23} ln w_2 ln q_3	0.007	***	0.0023
α_3 ln q3	0.255	***	0.0387	γ_{24} ln w_2 ln q_4	–0.002	-	0.0032
α_4 ln q_4	0.218	***	0.0592	δ_1^a d_6	–1.788	**	0.8121
α_{11} ln q_1 ln q_1	–0.020	-	0.0179	δ_2^a d_7	1.518	**	0.7458
α_{12} ln q_1 ln q_2	–0.017	**	0.0079	δ_3^a d_8	0.872	*	0.8722
α_{13} ln q_1 ln q_3	–0.018	***	0.0047	δ_1^c d_9	–4.953	**	2.0551
α_{14} ln q_1 ln q_4	–0.014	-	0.0112	δ_2^c d_{10}	-0.053	-	1.124
α_{22} ln q_2 ln q_2	–0.025	***	0.0089	δ_3^c d_{11}	5.660	*	2.9165
α_{23} ln q_2 ln q_3	–0.006	*	0.0033	γ_1 ln z_1	0.106	***	0.0345
α_{24} ln q_2 ln q_4	–0.015	**	0.0064	γ_2 ln z_2	0.020	***	0.0065
α_{33} ln q_3 ln q_3	–0.023	***	0.0085	γ_3 ln z_3	0.124	***	0.0179
α_{34} ln q_3 ln q_4	–0.004	-	0.0051	ς_{11} ln w_1 ln d_1	–0.064	***	0.0116
α_{44} ln q_4 ln q_4	–0.041	***	0.0087	ς_{12} ln w_1 ln d_2	0.043	***	0.0140
β_1 ln w_1	0.366	***	0.0299	ς_{13} ln w_1 ln d_3	0.025	**	0.0127
β_2 ln w_2	0.538	***	0.0214	ς_{14} ln w_1 ln d_4	0.091	***	0.0111
β_{11} ln w_1 ln w_1	0.053	***	0.0033	ς_{15} ln w_1 ln d_5	-0.003	-	0.0124
β_{12} ln w_1 ln w_2	0.006	***	0.0016	ς_{21} ln w_2 ln d_1	0.083	***	0.0080
β_{22} ln w_2 ln w_2	0.061	***	0.0038	ς_{22} ln w_2 ln d_2	–0.064	***	0.0093
γ_{11} ln w_1 ln q_1	–0.005	-	0.0061	ς_{23} ln w_2 ln d_3	0.010	-	0.0088
γ_{12} ln w_1 ln q_2	0.008	***	0.0026	ς_{24} ln w_2 ln d_4	0.007	-	0.0088
γ_{13} ln w_1 ln q_3	0.006	***	0.0022	ς_{25} ln w_2 ln d_5	–0.013	-	0.0083
γ_{14} ln w_1 ln q_4	–0.002	-	0.0041	σ_R	-0.039	–	0.0432
				σ_1	-0.028	***	0.0104

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Notes: Identification of parameters follows equations (4) and (5) for the δ parameters associated with the demographic variables *d*. The additional parameter σ_1 is the coefficient associated with the Heckman's correction factor; the additional parameter σ_R is the coefficients associated to the instrumental variables used in the estimation, which are respectively the and the 2SRI error term for endogeneity correction using both external and generated instruments as explained in the Appendix.

Table 6. Allen Elasticity of Substitution for Hired Labor, Chemicals,

and Materials

Hired Labor	Chemicals	Materials
–3.463	1.152	0.229
1.152	–1.630	0.601
0.229	0.601	–0.383

Table 7. Marginal Effects of Farm Characteristics and Fixed Factors

Variable	Coefficient
Farm Characteristics	
Terai	–0.235
Eastern	0.130
Central	–0.147
Sharecropping	–0.457
Subsistence Farming	0.061
Fixed Factors	
z1 - Adult labor	0.106
z2 - Child labor	0.020
z3 -Fixed assets	0.124

Table 8. Means of Adults' and Children's Shadow Wages

Variable	$E(w_i^*)$ (a)	$E(w_i^*\|z_2 > 0)$, (b)	$E(w_i^*\|z_2 = 0, \text{nch}_{1014} = 0)$ (c)	$E(w_i^*\|Sb = 1)$ (d)	$E(w_i^*\|z_2 > 0, Sb = 1)$ (e)	$E(w_i^*\|z_2 = 0, \text{nch}_{1014} > 0, Sb = 1)$ (f)
Adult labor	2.258	1.186	3.613	1.901	0.937	3.191
Child labor		0.882			0.507	
Child/Adult Ratio		0.744			0.541	

Note: Shadow wages are in rupees per hour. The market wage for hired labor is 1.863 rupees per hour.

Table 9. Contribution of the Demographic Attributes to the Marginal Cost of Household Labor

Attributes	Percentage	
Adults		
Head_sex	-17.880	**
Home_produc	15.175	**
Tech	8.723	*
Children		
Students	-49.535	**
Child_age	-0.526	-
Cons_Score	56.604	*

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 10. Poverty and Inequality Simulation as Child Labor Varies

	NLSS	Farm Households	Farm Households	
			Without working children	with working children	
				actual data	simulation
No. of observations	3,373	2,380	1851	529	
			Poverty indexes		
Headcount ratio	34.450	39.580	35.547	53.308	68.095
Poverty gap ratio	9.763	11.148	9.665	16.335	26.063
FGT index (0.5)	17.168	19.641	17.347	27.668	40.047
FGT index (1.5)	6.009	6.862	5.855	10.385	18.077
FGT index (2.0)	3.904	4.466	3.759	6.941	13.114
Sen index	13.321	15.258	13.262	22.130	34.378
			Inequality indexes		
Relative mean deviation	0.345	0.252	0.253	0.230	0.235
Coefficient of variation	1.223	0.834	0.837	0.713	0.730
Standard deviation of logs	0.772	0.607	0.609	0.558	0.592
Gini coefficient	0.466	0.351	0.352	0.320	0.330

Note: The annual per capita poverty line is set at 4,404 rupees.

Table 11. Summary Statistics of the External Instruments. No. of Observations 2,380

Variable	**Definition of Variables**	**Mean**	**Std. Dev.**	**Min**	**Max**
Rural	dummy: 1 if rural	0.931	0.254	0	1
Cart	dummy: 1 if cart is owned	0.061	0.239	0	1
Ch_gender	ratio of boys and girls in self-employed working condition	0.112	0.306	0	1
Fam_size	family size	6.397	2.941	2	29

Table 12. Validity and Relevance of the Selected Instruments and Endogeneity Test

Instrumented variable	**Testing instruments for**	**F**	**p-value**
z_2 - log of children on-farm working hours	Relevance (Wald test)	419.30	0.0000
	Validity (Sargan test)		0.1629
	Endogeneity (Durbin Hausman Wu test)	0.11	0.7457
z_1 - log of adult on-farm working hours	Relevance (Wald test)	48.75	0.0000
	Validity (Sargan test)		0.6111
	Endogeneity (Durbin Hausman Wu test)	23.18	0.0000

APPENDIX: Endogeneity of Adult and Child Quasi-fixed Labor

Family labor is a factor that can be considered fixed in the short run but is allocable in the different farm activities. Because of this nature and the possibility of measurement error due, for example, to the unobservability of managerial ability, endogeneity of family labor may arise. Because our modified translog cost function is non-linear in variables and parameters, the Two Stage Least Squares (2SLS) IV estimator can be implemented as a Two-Stage Predictor Substitution (2SPS) or a Two-Stage Residual Inclusion (2SRI) (Terza, Basu, and Rathouz 2008). Both approaches share the same implementation of the first stage by using the auxiliary equation $x_2 = g(z;\gamma) + \eta$, where g is a function nonlinear in z, x_2 are the endogenous regressors, z is a vector of instruments that includes the exogenous variables x_1 and the instrumental variables z_2, γ are the associated coefficients and η is a spheric error term. The difference between the two approaches lays on which information from the first stage is used in the second stage. In the 2SPS method, as in the linear 2SLS, the observed endogenous variable x_2 is substituted in the second stage with its prediction $\hat{x}_2$ obtained from the first stage. In the 2SRI method, as in the linear control function approach, the predicted residual from the first stage regression $\hat{\eta}$ is included as an additional regressor (Lewbel, Dong, and Yang 2012)

$$y = n(x_1, x_2, \hat{\eta}; \beta) + u,$$

where n is a non-linear function, x_1 and x_2 are respectively the exogenous and endogenous variables, $\hat{\eta}$ is the predicted error term from the first stage, β are the estimated coefficients and u is the error term.

In the presence of auxiliary regressions linear in parameters, as in our case, it is possible to exploit heteroskedasticity in the error terms to generate instruments when external instruments are not available or to improve the efficiency of (weak) external instruments (Lewbel 2012). Following this approach, the endogenous variable x_2 is regressed on a set of exogenous variables $x_2 = g(x_1;\delta) + \xi$, where δ are the regression coefficients and ξ is the error term. The predicted residuals are multiplied by mean-centered exogenous variables to construct the generated instruments

$$z_{2i}^{g} = (x_{1i} - \bar{x}_{1i})\hat{\xi} \;\; \forall\, i = 1, \dots x_1 \,,$$

where z_{2i}^{g} is the i-th generated instrument, x_{1i} and $\bar{x}_{1i}$ are respectively the i-th exogenous variables and its mean value and $\hat{\xi}$ is the predicted error term. The generated instruments are then used in the standard first stage auxiliary equation $x_2 = g(z;\gamma) + \eta$, where now z is a vector of instruments that includes the exogenous variables x_1 and the generated instrumental variables z_2^g. Using the information from the first stage auxiliary equation that is included in the second stage regression it is possible to rely either on a 2SLS or 2SRI approach. Both approaches can host the implementation of a mixed method using external instruments in combination with the generated instruments.

Because of the potential presence of endogeneity, we test for adult and child on-farm labor using residence, the ownership of a cart, child gender and family dimension as instrumental variables. Table 11 reports the corresponding descriptive statistics. The instrumental variables are verified for relevance by Wald test and validity by a Sargan test (Table 12). Testing for the presence of endogeneity by a DHW test suggests that adult on-farm family labor is endogenous.

Because our model is nonlinear both in variables and parameters, due to the presence of the modifying function, we implement the 2SRI approach that provides unbiased and consistent estimates (Terza, Basu, and Rathouz. 2008). Therefore, we regress by NLS the endogenous variable of the adult on-farm labor on the exogenous variables, the selected external instruments and/or the generated ones. The results from the mixed approach, using the external instruments in combination with the generated one are reported in Table 5.