Weak Ties, Labor Migration, and Environmental Impacts: Towards a Sociology of Sustainability

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Abstract

Debate about the substitutability of manufactured, natural, human and social capital is at the heart of sustainability theory. Sociology can contribute to this debate by examining the processes and mechanisms by which one form of capital is substituted for another. We examine the substitution among different forms of capitals at China's Wolong Nature Reserve where the consumption of an important aspect of natural capital, fuelwood, has serious consequences for the local environment. We found that social capital in the form of weak social ties to people in urban settings had significant impacts on rural-urban labor migration. Following the chain of capital substitutions, labor migration then significantly affected income, which in turn affected fuelwood consumption.

Key words: China, environmental impacts, labor migration, natural capital, propensity score, social capital

1. Introduction

At least since the Bruntland Commission (World Commission on Environment and Development, 1987), international policy has been concerned with the practices that affect sustainability (see also International Union for the Conservation of Nature, 1980; Rockwood et al., 2008; U.S. National Research Council, 1999). Sustainability also has spurred a vibrant literature in resource, environmental, development and ecological economics with some contributions from political science and philosophy (Becker and Ostrom, 1995; Clark and Dickson, 2003; Henry, 2009; Kates et al., 2001; Norton, 2005). However, we cannot point to a sociological approach to sustainability. The challenge for sociology is to develop an approach that embraces the study of coupled human and natural systems (Liu et al., 2007), while bringing the benefits of traditional sociological concerns to bear.

Although the term sustainability is often deployed in vague ways (Blühdorn, 2007; Blühdorn and Welsh, 2007) the core debate in sustainability theory is over the degree to which "natural capital", defined as the goods and services humans derive from ecosystems (Costanza et al., 1997; Daily et al., 2000), can be replaced by "manufactured capital,"[1] in the form of increased affluence. Neoclassical economic theory suggests that the factors of production—land (natural resources/ natural capital), manufactured capital and labor—can be substituted for one another to a substantial degree (Hubacek and van den Bergh, 2006). Thus it may make good sense for a nation to deplete natural resources and use the proceeds of their sale to invest in, for example, transportation infrastructure (manufactured capital). However, if some forms of capital

[1] Unfortunately, there are multiple terms for what we are calling manufactured capital, including physical capital and financial capital. For the micro-level analysis we conduct, distinctions among these terms and the attendant conceptualizations need not be explored but this is clearly an area in need of theoretical development.

have unique properties that are not substitutable, depleting them may cause serious harm to future generations.

This debate about capital substitution provides a natural entry point for sociology. Starting in the 1990s, the argument was made that the set of capitals to be considered should be expanded beyond natural and manufactured capital to include human and social capital (Arrow et al., 2004; Bebbington, 1999; Dietz et al., 2008; Serageldin and Steer, 1994).[2] Sociology can contribute to this discussion because the substitution of one form of capital for another is not a mechanical or automatic process but an active one (Bourdieu, 1986) that often involves use of social capital, defined as the resources people access through social relations/ties (Lin, 2001; Portes, 1998). For example, rather than merely apply for a job to sell labor, one might use a friend to secure a job and then repay the friend with part of one's earnings, goods, or some other non-monetary form of compensation. These transactions are not direct exchange, may involve an element of delay and depend to a substantial degree on trust (Coleman, 1995). Therefore, a sociology of sustainability, in tracing the processes of capital substitution, examines how

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[2] The argument for the importance of four capitals—manufactured, natural, human and social—seem to have first been articulated in a short essay by Serageldin and Steer (1994). Bebbington (1999) used five capitals, adding "cultural" as the basis for what has come to be known as the livelihoods approach to development. Our approach is very much parallel to the livelihoods approach in emphasizing the agency households deploy in gaining access to and making use of various forms of capital (Scoones 2009). We have not included "cultural" capital in our framework as it has never been precisely defined, and in Bebbington's work is essentially a sense of identity or place and is clearly not fungible with the other forms of capital.

individuals, households and more aggregate actors develop strategies to use capital and face constraints in realizing those strategies.[3]

1.1. Sustainability in A Transforming Economy

We apply our analysis of the substitution of capital to decisions ultimately affecting household energy use in Wolong Nature Reserve in the rapidly changing economy of China. The reserve is a source of natural capital for its human inhabitants because they make extensive use of fuelwood for heating and cooking. But that practice has substantial adverse effects on the local ecosystem, and especially the habitat of giant pandas (An et al., 2005). Electricity is available locally and can displace fuelwood use, but there are few opportunities in this very rural area to obtain the income necessary to use electricity, so a direct substitution of income for natural capital is not feasible for most households. However, the households in the reserve also possess human and social capital and can use those resources as a basis for labor migration and wage income. This leads to the possibility of what we term "chain substitution." Local residents may be able to deploy social capital to obtain jobs that allow a return to income from their human capital, and use the income to modify their use of natural capital.

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[3] One way of enhancing well-being over the longer term is by deploying capital resources to enhance one's power and to use power to change the substitutability of one form of capital for another and thus their relative value. Because power differentials are not prominent in the context we examine here, we will not elaborate these linkages but clearly the relationships among the four capitals and the role of agency and structure in shaping access to and use of them remain undertheorized and should be a key element of a sociology of sustainability. For example, Braverman's (1974) analysis of the deskilling of labor can be viewed as a strategic effort by those with control of manufactured capital to reduce the value of human capital and thus the cost of replacing human capital with manufactured capital.

While access to markets in which to sell labor can be taken as given for most individuals in an advanced capitalist economy, access to labor markets that allow human capital to generate income can be problematic in economies in transition.[4] Without institutions and infrastructure for banking, insurance, or transportation, workers in transforming economies cannot simply present themselves for work in a nearby factory or retail establishment. They must find the job opportunities, get transportation to the worksite, and in many cases be willing to temporarily relocate. Many of these actions require social capital as informal social relations can provide information about jobs, transportation to jobs, and can act as a third party guarantor of commitment to jobs (Fernandez et al., 2000). This suggests a chain substitution of capitals and in particular the use of social capital to gain employment and thus income (Granovetter, 1973).

1.2. Environmental Change in Contemporary China

China provides an important context in which to explore these ideas. Several recent analyses document the impact of human behavior on the environment in China (Economy, 2004; Liu and Diamond, 2005). While problems of industrialization, such as air and water pollution, are the most visible, local communities are placing serious strains on several critical habitats. For instance, the use of wood for cooking and heating can have substantial impact on local environment, such as our study site, Wolong Nature Reserve for the protection of the world-famous endangered giant pandas (Liu et al., 2001). Unlike many nature reserves in western

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[4] In most labor markets, there are income rewards to human capital in the sense that individuals with more human capital tend to receive more income for their labor. However, as Wright (1979) demonstrated, the relationship between human capital and income depends upon social class. Again, a sociology of sustainability could profitably explore the role of class in the use of manufactured, natural, human and social capitals in the generation of well-being at both the micro and macro levels.

countries, a substantial rural population (approximately 4500 in 2004) inhabits two townships, Wolong and Gengda, in the reserve (Figure 1). More than 95% of the inhabitants are farmers living in isolated farmsteads. Their traditional livelihood depends heavily on natural capital and includes farming, fuelwood collection and livestock breeding. Fuelwood collection has been demonstrated to have an especially pronounced impact on panda habitat because the amount of fuelwood collected by inhabitants is very substantial, with a mean of over 6,000 kilograms per household per year, resulting in the removal of forest canopy that provides shelter and cover for pandas (An et al., 2005). As a result, the panda habitat has suffered from serious degradation (Liu et al., 2001).

The inhabitants of the reserve have an alternative to obtaining energy from wood. Due to China's recent investment in hydroelectric power, electricity has become more available and more reliable. In fact, all households in the reserve have access to electricity. In our interviews, the residents of the reserve indicated they preferred electricity to fuelwood because it is more convenient, cleaner, and required less labor for gathering.[5] In contrast to electricity, fuelwood is free except for the labor required for extraction.[6] However, the cost of electricity has increased recently, in large part to offset the large government investments in producing electricity. Thus the primary obstacle to the use of electricity is economic, and a key factor for improving economic status is through taking off-farm employment. So local residents have potential to

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[5] Fuelwood is not sold at the local market, and farmers in the reserve collect fuelwood mainly in winter for their own use in the following year.

[6] Although the reserve administration has developed several policies to reduce fuelwood collection, monitoring and enforcement of these policies are a problem because the settlements and fuelwood collection are very geographically dispersed.

substitute income for the use of natural capital, and would prefer to do so, but their ability to use human capital as labor to generate income locally is limited.

Wolong Nature Reserve is just beginning to be affected by the move towards a market economy and urbanization forces that have affected the rest of China since the 1990s. However, some inhabitants now complement their traditional economic activities based on the use of natural capital by working in urban settings through temporary rural-urban labor migration. Previous research on labor migration has suggested that the remittance from migrants may substantially improve the livelihood of their rural households (Airola, 2007; Koc and Onan, 2004).

In the reserve, labor migration may have substantial impacts on the local ecosystem in several ways. First, remittances from labor migrants may be used to shift rural energy consumption from fuelwood to electricity. As de Sherbinin et al. (2008) have noted, "the empirical research on remittances and the environment is sparse." Second, labor migrants may also contribute to rural household economy through sending materials (e.g., food, clothes, and electronic appliances) back home, which may free up income for purchasing electricity. Third, the reduction of the local human population due to labor migration may reduce energy needs (both fuelwood and electricity) of rural households (An et al., 2005). Fourth, labor migration may reduce the labor supply for collecting fuelwood (Rudel and Roper, 1997; Tole, 1998). Thus the relationships among labor migration, fuelwood consumption and electricity consumption may be complex.[7]

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[7] Migration also has the potential to introduce new ideas and norms into the community. Thus labor migrants might introduce a preference for "modern" energy sources such as electricity over traditional sources such as wood. However, field experience indicates that the preference for electricity is already widespread among those living in

1.3. Labor Migration Patterns in China

For the most part, the labor migrants of the reserve do not migrate to urban areas to settle permanently. Instead they seek temporary employment in urban settings and return to their home villages whenever needed (e.g., in planting or harvesting seasons). In this sense, they take advantage of the rapid economic development in China in seeking temporary jobs, but are not permanent urban residents in the larger urbanization process. Such temporary migration is very common in China as well as many other parts of the world (Korinek et al., 2005; United Nations, 2004). In the case of Wolong Nature Reserve, in 2004, 162 people worked in cities through temporary labor migration. Although the proportion of labor migrants is small (accounting for about 6.0% of eligible laborers in the reserve), it is substantial compared with many other rural areas in China (Li and Zahniser, 2002), and is increasing rapidly (Liu Mingchong, 2005, personal communication).

The determinants of labor migration and the relationship of such labor migration to macro political and economic changes have been carefully studied in contemporary China (Fan, 2003; Goldstein et al., 1997; Li and Zahniser, 2002; Liang, 2001; Yang, 2000). The standard model of labor migration examines how households use human capital (e.g., age, education and gender) to generate income via labor migration (Angrist and Evans, 1998; Becker, 1985; De Jong, 2000). Yet few studies have explored the impact of social capital in the context of Chinese internal migration (Zhang and Li, 2003).

It is well known that social capital may affect migration decisions (Hugo, 1998; Massey, 1990; Palloni et al., 2001) and facilitate migration processes (e.g., help migrants settle down and

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the Reserve, so while "cultural remittance" may be important in many circumstances (Levitt 1998), it is not a major factor here.

become familiar with places of destination) so that costs and risks of migration may be mitigated (Korinek et al., 2005). Social capital is also important for accessing employment information and influence (i.e. influential persons in particular labor subsectors) (Bian, 1997; Granovetter, 1995; Lin et al., 1981; Yakubovich, 2005). When characterizing social capital, it is important to differentiate the strength of social ties as ties with different strengths may have different roles in facilitating labor migration. For instance, relatives may be perceived as stronger ties than friends, while friends may be perceived as stronger ties than acquaintances (Bian, 1997; Granovetter, 1995). Strong social ties may be more reliable in facilitating migration processes such as transportation and settlement, while weak social ties may expand information about employment opportunities (Massey and Espinosa, 1997; Wilson, 1998). Moreover, weak ties may provide direct access to influence, while strong ties are usually indirectly associated with influence (Bian, 1997; Granovetter, 1995; Yakubovich, 2005).

Granovetter (1973; 1995) explained how ties, in particular weak ties, might affect employment seeking. His arguments are very salient for the reserve located in a mountainous rural area far from any urban areas (>100 km), which makes communication between the reserve and the outside difficult. Without any government institutions or other formal organizations providing employment information, social capital is an important source of such information. Without social capital it may be very difficult for a household to use human capital to generate income.

To understand the environmental impact of labor migration in the reserve, we must retrace a causal chain of substitution that starts with the use of fuelwood, from there back to the economic and demographic impacts of labor migration, and finally from labor migration to the social capital that facilitates such migration. Our model is summarized in figure 2. Building on the classic effects of social ties on labor outcomes, our first hypothesis is that access to social capital, especially weak social ties, facilitates labor migration. The second hypothesis is that labor migration reduces household fuelwood consumption, as income is substituted for the use of natural capital. Thus the resources individuals access through social relations indirectly affect fuelwood consumption. Our analysis elucidates the links between social relations, labor migration and fuelwood consumption and thus shows the processes by which one form of capital is substituted for another.

2. Material and Methods

Our in-person interviews were conducted from May to August 2005 in the Wolong Nature Reserve. We interviewed with 129 households with temporary labor migrants (comprising 152 labor migrants) and 215 households without labor migrants in 2004 (See Appendix 1 for further details on sampling procedures). We collected socio-demographic information on individual members and economic, social ties and fuelwood consumption data for households. We asked the average amount (weight) of daily fuelwood consumption in the previous year for both the winter season when more fuelwood is needed and the summer season when less fuelwood is needed. Household fuelwood consumption was therefore measured as a summation of daily consumption across the year. As noted above, previous studies in this reserve have identified fuelwood collection as one of the main reasons of the degradation in the local ecosystem (An et al., 2005; Liu et al., 2001).

In households without labor migrants, we asked respondents about their social ties with people who were living or working (including temporary migrants) in cities outside the reserve. Since labor migration could lead to social ties, in households with labor migrants we asked respondents to recall their social ties before migration. We measured the strengths of social ties with relatives considered as strong ties, acquaintances as weak ties, and friends as ties of moderate strength. We also asked if each type of their tie included people holding leadership positions. Our measures of social ties in households with labor migrants are retrospective to their pre-migration social network. Although accurate recall of social ties is difficult (Bernard et al., 1984; Marsden, 1990), people tend to report social ties with whom they have more interactions (Feld and Carter, 2002; Neyer, 1997) and hence are more important for activities such as labor migration. We used dummy variables to denote the availability of various social ties because measures of network size tend to be biased in retrospective studies (Brewer, 2000). Wolong Nature Reserve is a relatively isolated area where inhabitants do not have many ties to the outside, so dichotomous measures of social ties still capture most of the variation in social resources among households. In households with labor migrants, we asked how much remittance labor migrants send back home.

2.1. Causal Inference

Because of self-selection into labor migration, the relationship between migration and fuelwood consumption may be confounded with other factors. In the absence of a randomized or natural experiment assigning people to migrate or not, any estimated effect of labor migration on an outcome may be spurious. This is reflected in the fundamental counterfactual question: “How much fuelwood would a household with labor migrants have consumed if the household member(s) had not temporarily worked outside of the reserve?” This question is counterfactual because we cannot observe the fuelwood consumption of households with labor migrants under the condition of no one working outside of the reserve. Neglect of this self-selection process can result in invalid inferences (Hirano and Imbens, 2002; Winship and Morgan, 1999).

We approximate counterfactual conditions using propensity score weighting (Hirano and Imbens, 2002; Morgan and Harding, 2006; Robins and Rotnitzky, 1995; Rosenbaum and Rubin, 1983). Propensity score techniques use the logic of comparing individuals in the treatment group (in our case, the treatment group is composed of the households with temporary labor migrants) to individuals in the control group (households without labor migrants) with a similar propensity score (likelihood of working outside). The propensity score is defined as (Rosenbaum and Rubin, 1983):

$$e(x) = \Pr(m = 1 \mid x), \qquad (1)$$

where *m* is a dummy variable indicating treatment (i.e. 1 if one or more members of a household were working outside the reserve; 0 otherwise); *e(x)* is the propensity for receiving the treatment and can be estimated using a logistic regression model using covariates *x* (e.g., household level human capital and economic conditions, geographical information, and social capital).

We use weights based on the propensity scores in estimating the average causal effect of labor migration on fuelwood consumption (Hirano and Imbens, 2002; Robins and Rotnitzky, 1995). The weights are defined by

$$\omega(m, x) = \frac{m}{e(x)} + \frac{1-m}{1-e(x)}. \qquad (2)$$

Therefore, a household with migrants is weighted by $1/e(x)$ and a household without migrants is weighted by $1/(1-e(x))$. In other words, the lower the propensity of having migrants for those households with labor migrants, the greater weight they are given. Similarly, the higher the propensity of having migrants for those households without migrants, the more weight they are given. In this way, the estimation of the average causal effect focuses mainly on the strongest overlap in propensity, those with lower propensity in the treatment group and those with higher propensity in the control group (Figure 3 and Appendix 1).

Under some circumstances, separate causal effects for the migration group and the non-migration group are of interest. To estimate the effect of labor migration for those households in which a member was working outside of the reserve, the following weights can be used:

$$\omega_{mi}(m,x) = m + (1-m)\frac{e(x)}{1-e(x)}. \quad (3)$$

Thus those working outside of the reserve are weighted with a value of one, and members of the comparison group are given more weight if they have a higher propensity to migrate. As a complement, to estimate the effect of temporary labor migration for those households in which no one was working outside the reserve, the following weights can be used:

$$\omega_{nonmi}(m,x) = m\frac{1-e(x)}{e(x)} + (1-m). \quad (4)$$

Here those households in which no one was working outside the reserve are assigned a weight of one, and those with labor migrants are given more weight if they have a lower propensity to migrate.

2.2. Analytical Approach

We first model the propensity for labor migration as a function *inter alia*, of social ties. Then we estimate the effect of labor migration on fuelwood consumption. All laborers (912 people) from the 344 households that we interviewed are used in logistic regression models to estimate the propensity for labor migration. Based on past studies of labor migration in China (Fan, 2003; Goldstein et al., 1997; Li and Zahniser, 2002; Liang, 2001; Yang, 2000; Zhang and Li, 2003), we chose both individual level and household level factors as potential determinants of temporary labor migration. At the individual level, we chose gender, age, marital status, education level, number of children younger than 15 years of age and availability of extended household member. At the household level, we chose amount of land, non-migration income (measured by excluding migration income from total household income), number of laborers (18~60 years of age, people beyond this range usually do not work outside) and indicator of township the household is located. We extend the model specifications suggested in the literature by adding social capital to these individual and household level human capital and income and wealth factors.

The first model includes three dummy variables denoting the availability of relatives, friends and acquaintances living or working in cities outside the reserve. In models two through four, we isolate effects of each particular tie as well as the extent to which the ties hold leadership positions. The fifth model controls for the availability of any of the three types of social ties and any ties to people holding leadership positions outside the reserve. We use the last model to calculate the propensity weights because it has the best fit. Moreover, because this model includes the primary factors predicting labor migration described in the literature as well as measures of social capital we use it as a basis of causal inference in the absence of a randomized experiment (Shadish et al., 2002).

Next, we use the estimated propensities to weight a standard regression of the effect of labor migration on fuelwood consumption. In addition to the migration status of households (measured with an indicator of whether or not a member of the household had engaged in temporary labor migration in 2004), we control for household size, availability of senior members (people over 60 years of age), household income, amount of land, number of pigs the household had, and an indicator of the household's township as covariates in fuelwood consumption models. We hypothesize that there are effects of labor migration on fuelwood consumption beyond the direct economic returns from labor migration because migration reduces household labor for gathering fuelwood and decreases demand as a result of the absence of a household member. In addition, migrants may also send materials (e.g., food, clothes, and electronic appliances) home. To reflect the potential indirect effects of labor migration, total household income, as an alternative to non-migration income, is accounted for in some fuelwood consumption models.

We use all working age individuals (household members from 18 to 60 years of age) as units of analysis in estimating the propensity model because it is individuals who choose whether or not to work outside the reserve. Since we also use some household predictors (e.g., amount of land owned by the household) in this model, we corrected for the lack of independence among members of the same household using Huber's variance correction (Wooldridge, 2002). We analyze fuelwood consumption at the *household* level because fuelwood is consumed by households. The highest propensity score of any individual in the household is assigned to the household in that few households had more than one labor migrant.

Because there is uncertainty in the estimates of the propensity scores that are used in weighting our fuelwood consumption models, we use case based bootstrapping to calculate standard errors (Efron and Tibshirani, 1993). For each estimate of the propensity and fuelwood consumption models, we calculate standard errors from 500 bootstrap replicates that are then the basis for t-ratios.

3. Results

3.1. Data Summary

Our sample includes 129 households with labor migrants and 215 households without labor migrants. Summary statistics of individual level variables are presented in Table 1. About 52% of 912 laborers were male with an average age of 36 years, and 79.1% of the laborers were married. The mean number of years of education was 6. On average, each of these laborers had less than one child under 15 years, and about half the laborers lived with extended household members such as parents or parents-in-law. Labor migrants accounted for 16.7% of 912 laborers.

At the household level, the mean household size was 4.7 people, while the mean number of laborers was 2.7 (Table 2). About 1/3 of these households had senior members. The mean non-migration income was 10.253 thousand yuan,[8] and the mean total household income was 11.377 thousand yuan. On average, each household owned 0.282 hectares of cropland, breed about 3 pigs, and about 60% of these households were located in the Gengda township. About half of the households had relatives working or living in urban areas, but less than half of these relatives held leadership positions (Table 2). Only about 19% and 24% of the households had friends and acquaintances working or living in urban areas respectively, and few of these ties held leadership positions. More strong ties (i.e. relatives) were reported than weak ties (i.e. acquaintances) presumably because people tend to report social ties with whom they have more interactions (Feld and Carter, 2002; Neyer, 1997). By combining different types of social ties, 66.3% of the households had social ties in urban areas and 30.2% of the households had ties with people holding leadership positions. The proportion of households with labor migration in the overall study area was 11.9% but in our stratified sample 37.5% of households had labor migrants. On average, each household in our sample consume 6325 kilograms of fuelwood.

3.2. Determinants of Labor Migration

Models of the determinants of temporary labor migration are presented in Table 3. Model 1 shows that households with weak ties (i.e. acquaintances) were significantly ($p \leq 0.001$) more likely to have labor migrants than were other households—this form of social capital facilitates

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[8] At the time of the study 1 USD = 8.3 yuan.

being able to use human capital to produce income. The effect of relatives, representing strong ties, is not statistically significant. These results are consistent with Granovetter's "the strength of weak ties" hypothesis (Granovetter, 1973, 1995). Holding all other factors constant, the availability of an acquaintance increases the odds of labor migration by 2.54, while the effects of the availability of relatives and friends on labor migration do not significantly differ from zero (see model 1 in Table 3). When exploring different types of social ties separately controlling for demographic and economic factors as covariates (see models 2 through 4), the availability of relatives and friends working or living in urban areas does not have significant effects on labor migration, while the availability of acquaintances still has a significant ($p \leq 0.01$) positive effect on labor migration with a similar magnitude as that in model 1. Moreover, the insignificance of ties holding leadership positions indicates that leadership ties were not more helpful than non-leadership ties. When different types of ties were combined (model 5; AIC = 587.629, pseudo R^2 = 0.319), the availability of social ties in cities outside of the reserve significantly ($p \leq 0.01$) increased people's odds of labor migration by 2.21 net of other factors. Thus social capital is, as expected, very important in obtaining income from labor.

Human capital and economic conditions had similar effects across the 5 models (all estimates reported net of other factors). It is not surprising that human capital was very important. The odds that men would work outside the community were 2.82 time higher than the odds for women ($p \leq 0.001$), a result consistent with the norm in rural areas of China that men are usually expected to assume economic responsibility in the household. Both age and its quadratic term had significant ($p \leq 0.05$) effects on labor migration. The quadratic relationship between age and migration shows that the probability of migration increases until 30 years and then declines as age increases. The odds of labor migration for married people is only about 0.21 times of that for unmarried people. Each additional year of education increases the odds of labor migration by a factor of 1.2 ($p \leq 0.001$). No effects of extended household member(s) and the number of children under 15 years were detected. The number of laborers had a significant ($p \leq 0.05$) positive effect on labor migration with each additional household laborer increased the odds of labor migration by 1.39 (Model 5 in Table 3). Amount of cropland of the household did not have a significant effect on labor migration. Non-migration income had a significant ($p \leq 0.01$) negative effect on labor migration, decreasing the odds of labor migration by a factor of 0.93 with an increase in non-migration income of one thousand yuan. These effects are consistent with the fact that labor migration is a way of finding alternative opportunities for those who have the most limited opportunities in the reserve. Finally, residing in Gengda township had a significant ($p \leq 0.01$) positive effect on labor migration. The odds of labor migration for people in the Gengda township was 2.29 times of that for people in the Wolong township. This reflects the fact that the Gengda township is geographically closer to urban areas outside the reserve so its inhabitants have access to more information and material exchanges with the outside than those living in the Wolong township. Our results of the determinants of temporary labor migration are consistent with many other empirical studies at regional or national levels in China (Fan, 2003; Goldstein et al., 1997; Li and Zahniser, 2002; Yang, 2000).

3.3. Estimation of the Effects of Labor Migration on Fuelwood Consumption

Estimates of the effect of labor migration on fuelwood consumption with propensity weighting are presented in Table 4. Fuelwood consumption of households with labor migrants was significantly less than fuelwood consumption of households without migrants. When non-migration income, together with other covariates, was included in the model, households with migrants consume 1827 kilograms less fuelwood (~28.9% of average annual household fuelwood consumption in the reserve) on average than those without migrants (*p*≤0.001). In contrast, the effect of labor migration without using weights was estimated to be 1647 kilograms (*p*≤0.001).

We also estimated the effects of labor migration separately for the migration groups and non-migration groups using estimate-specific weights (see equations 3 and 4). Labor migration had less effect on reducing fuelwood consumption for those households in the migration group (the 3rd row in the 1st column of Table 4), while the effect is strongest for those in the non-migration group (the 4th row in the 1st column of Table 4). Presumably, the difference is due to the differences in characteristics between these two groups. For example, a high propensity of labor migration may indicate that the household has more laborers, and a reduction of one laborer from a household that has many laborers may not affect as much the supply of labor for fuelwood collection as that from a household that has few laborers.

In addition to the direct economic contribution of labor migration, following the deforestation literature we also hypothesized indirect effects of labor migration on fuelwood consumption. To estimate these effects non-migration income was replaced with total household income with results reported in the 2nd column of Table 4. In this model, the effect of labor migration is net of the income it contributes to the household. Labor migration still has significant negative effects on fuelwood consumption, although the magnitude of effects is smaller than that when non-migration income was controlled for (1st column of Table 4). This suggests that labor migration has both a direct economic contribution and an indirect effect on reducing fuelwood consumption. The indirect effect may occur because migrant laborers send materials (e.g., food, clothes, and electronic appliances) home, and their absence may reduce both the need for fuel in the household and the labor available to gather fuelwood, and may even affect the lifestyles of their household (e.g., using electric stoves and other appliances which in turn may make electrical use routine for heating as well).

Although we have attempted to reduce bias in our estimate by controlling (through propensity score weighting) for many well recognized factors affecting labor migration and fuelwood consumption, we may have omitted confounding factors that could bias our estimates. Quantification of the validity of inferences suggests the inferences are robust with respect to concerns about omitted confounding variables (More detail on these analyses is provided in the Appendix 1).

4. Discussion

We have suggested that an appropriate sociological approach to sustainability is to consider the strategies individuals and households deploy to generate well-being from their income and wealth, access to natural capital, human capital in labor and social capital. This approach is consistent with the existing sustainability literature that emphasizes problems of capital substitution. But it adds to that approach to include the important sociological insight of the tension between agency, in the form of individual and household strategies, and structural constraints, in the form of limited access to some forms of capital.

In the Wolong Nature Reserve, the most crucial environmental threat is deforestation and the resultant degradation of panda habitat. Local residents use substantial amounts of natural capital in the form of fuelwood for cooking and winter heating. While the possibility of substituting electricity for fuelwood exists, the costs of electricity and the paucity of local opportunities to convert human capital, via labor, into income preclude this move away from the use of natural capital for most households—a structural constraint. However, our analysis shows that a form of social capital, weak ties, is often used to gain access to extra-local employment and that the income from this employment then displaces the use of local natural capital, a process of chain substitution.

In addition to providing a “demonstration of concept” for our proposed sociological approach to sustainability, our results also address two other issues in the literature. First, we have replicated in rural China a finding developed elsewhere—that among forms of social capital it is weak ties that matter most in finding opportunities to find employment (Garip, 2008; Pfeffer and Parra, 2009). We note that strong ties may produce weak ties, but in our research and that of others back to Granovetter (1973), it is weak ties that have the most impact.

Second, we have shown that, at least in the context of the Wolong Nature Reserve, the effect of labor migration on deforestation comes from the ability to use increased household income to purchase a substitute for local natural capital. It is well understood that labor migration can have substantial environmental consequences (Aide and Grau, 2004; Bilsborrow, 2002; Bilsborrow and Ogendo, 1992; Liu and Diamond, 2005; Rudel et al., 2002), an issue first raised by Marx (Foster, 1999). But as (de Sherbinin et al., 2008) emphasize, little empirical analysis has examined the environmental effects of remittances. Without in-depth understanding of how migration decisions are shaped by context and why they vary across individuals and households, it is hard to understand the dynamics and impacts of migration and ultimately the environmental consequences of migration (Walker, 2008). Our results also reflected some earlier findings on labor migration and deforestation that emphasize the loss of labor supply as the mechanism by which extra-local employment eases deforestation (Rudel and Roper, 1997; Tole, 1998).

The overall adverse effects of Chinese economic development are well documented (Liu and Diamond, 2005) and by 2015 China is projected to have, after the U.S., the second largest ecological footprint of any nation (Dietz et al., 2007). Policy efforts to ameliorate this impact and move China and other economies in transition towards a more sustainable path must be designed with sensitivity to local context to avoid perverse effects (Liu et al., 2007). The effects of weak ties in the Wolong Reserve communities suggest a relatively low-cost mechanism to encourage the substitution of income for use of local natural capital. In the reserve, it appears that access to extra-local labor markets is the key structural constraint on household strategies. Creating local labor markets that allow exchange of labor for income is difficult and the ability to do so without violating the sustainability goals of the Nature Reserve may be limited. However, enhancing social capital by providing better information on and access to extra-local labor markets is a relatively low cost policy option for government. In the case of Wolong this could reduce the demand on fuelwood. We must emphasize that the effects of reducing this structural constraint on deploying human capital to produce income is context specific and so might or might not reduce the use of local natural capital in other contexts. Developing effective policies requires careful analysis of how those influenced by the policies will respond.

Finally, while we have emphasized the household and individual as units that deploy capital to enhance their well-being, a sociology of sustainability should not limit itself to the micro level. Part of the sociological tradition is to consider not only individuals and households as agents but also communities, social movements, formal organizations, government and nations. Sociology could contribute fruitfully to our understanding of sustainability by examining the strategies used by these collective actors and the constraints they face in deploying the capital resources available to them.

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Figure Legends

Figure 1. Location and elevation of Wolong Nature Reserve in China.

Figure 2. The effect of social capital on the environment as mediated by labor migration.

Figure 3. Overlap in propensity scores between treatment group and control group.

Table 1. Descriptive statistics of individual level variables.

Independent Variables	Mean (Standard Deviation)
Male (male = 1 and female = 0)	0.520 (0.500)
Age (years)	36.034 (11.541)
Age Squared	1431.492 (889.042)
Married (married = 1 and single = 0)	0.791 (0.407)
Education (years)	5.998 (3.490)
Children (number of children with age $\leq$ 15 years)	0.867 (0.933)
Extended (1 if there is extended member in the household; 0 if no extended member in the household)	0.507 (0.500)
Migrant (1 if the individual is a labor migrant; 0 if the individual is not a labor migrant)	0.167 (0.373)

(n = 912)

Table 2. Descriptive statistics of household level variables.

Variables	Mean (Standard deviation)
Household Size (number of people in the household)	4.663 (1.288)
Laborers (number of working age people—18~60 years of age—in the household)	2.651 (1.061)
Senior (1 if there is senior member in the household; 0 if no senior member in the household)	0.326 (0.469)
Non-migration Income (thousands of Yuan)	10.253 (7.887)
Total Household Income (thousands of Yuan)	11.377 (9.376)
Land (hectares)	0.282 (0.152)
Pigs (number of pigs the household breed)	2.881 (2.159)
Gengda (Gengda township = 1 and Wolong township = 0)	0.599 (0.491)
Relative (1 if there is relative outside the reserve; 0 if no such relative)	0.517 (0.500)
Relative Leader (1 if there is relative outside the reserve holding leadership position; 0 if no such relative)	0.215 (0.412)
Friend (1 if there is friend outside the reserve; 0 if no such friend)	0.189 (0.392)
Friend Leader (1 if there is friend outside the reserve holding leadership position; 0 if no such friend)	0.061 (0.240)
Acquaintance (1 if there is acquaintance outside the reserve; 0 if no such acquaintance)	0.244 (0.430)
Acquaintance Leader (1 if there is acquaintance outside the reserve holding leadership position; 0 if no such acquaintance)	0.055 (0.229)
Tie (1 if there is any type of social tie outside the reserve; 0 if no tie outside the reserve)	0.663 (0.473)
Tie Leader (1 if there is any type of social tie outside the reserve holding leadership position; 0 if no such tie)	0.302 (0.460)
Migration (1 if there is labor migrant(s) in the household; 0 if no labor migrant(s) in the household)	0.375 (0.485)
Fuelwood Consumption (kilograms)	6325 (4499)

(n = 344)

Table 3. Determinants of labor migration models.

Independent variables	Coefficient (Adjusted standard error) [odds ratios]				
	Model 1	Model 2	Model 3	Model 4	Model 5
Male	1.029*** (0.222) [2.798]	1.037*** (0.214) [2.821]	1.034*** (0.217) [2.812]	1.044*** (0.223) [2.841]	1.035*** (0.222) [2.815]
Age	0.316** (0.117) [1.372]	0.320** (0.120) [1.377]	0.315** (0.121) [1.370]	0.325** (0.118) [1.384]	0.300* (0.121) [1.350]
Age Squared	-0.005** (0.002) [0.995]	-0.005** (0.002) [0.995]	-0.005** (0.002) [0.995]	-0.005** (0.002) [0.995]	-0.005** (0.002) [0.995]
Married	-1.725*** (0.344) [0.178]	-1.540*** (0.340) [0.214]	-1.644*** (0.335) [0.193]	-1.726*** (0.339) [0.178]	-1.563*** (0.361) [0.210]
Education	0.186*** (0.043) [1.204]	0.181*** (0.040) [1.198]	0.182*** (0.041) [1.200]	0.190*** (0.043) [1.209]	0.186*** (0.044) [1.204]
Children	0.072 (0.182) [1.075]	0.110 (0.184) [1.116]	0.091 (0.184) [1.095]	0.066 (0.182) [1.068]	0.067 (0.187) [1.069]
Extended	0.314 (0.312) [1.369]	0.417 (0.311) [1.517]	0.316 (0.318) [1.372]	0.287 (0.315) [1.332]	0.346 (0.315) [1.413]
Laborers	0.359** (0.126) [1.432]	0.336** (0.121) [1.399]	0.325** (0.124) [1.384]	0.348** (0.126) [1.416]	0.327* (0.129) [1.387]
Land	-0.267 (0.870) [0.766]	-0.108 (0.816) [0.898]	0.016 (0.863) [1.016]	-0.300 (0.826) [0.741]	-0.160 (0.859) [0.852]
Non-migration Income	-0.082*** (0.024) [0.921]	-0.069** (0.022) [0.933]	-0.065** (0.022) [0.937]	-0.079*** (0.024) [0.924]	-0.073*** (0.023) [0.930]
Gengda	0.782*** (0.238) [2.186]	0.907*** (0.235) [2.477]	0.937*** (0.238) [2.552]	0.793*** (0.238) [2.210]	0.830*** (0.246) [2.293]
Relative	0.196 (0.217) [1.217]	-0.015 (0.263) [0.985]			
Relative Leader		0.560 (0.323) [1.751]			
Friend	0.197 (0.281) [1.218]		0.061 (0.333) [1.063]		
Friend Leader			0.710 (0.513) [2.034]		
Acquaintance	0.930*** (0.244) [2.535]			0.892*** (0.274) [2.440]	
Acquaintance Leader				0.307 (0.384) [1.359]	
Tie					0.795** (0.294) [2.214]
Tie Leader					0.316 (0.268) [1.372]
Intercept	-8.003*** (1.959)	-8.045*** (1.958)	-7.848*** (1.991)	-8.009*** (1.956)	-8.126*** (2.014)
AIC	589.247	599.763	600.832	588.033	587.629
Pseudo R^2	0.319	0.304	0.303	0.319	0.319

* $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$ (two-tailed tests). n = 912 ($n_{mi} = 152$)

Table 4. Estimated effect of labor migration on fuelwood consumption (kilograms) using general linear models (GLM).

Models	Coefficient (Bootstrap standard error)	
	Covariates including non-migration income	Covariates including total household income
GLM: unweighted	-1647*** (467)	-1262** (461)
GLM: average effect of labor migration	-1827*** (242)	-1482*** (249)
GLM: effect for migration group	-1253** (424)	-988* (409)
GLM: effect for non-migration group	-2067*** (263)	-1668*** (279)

* $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$ (two-tailed tests). n = 344

Figure 1. Location and elevation of Wolong Nature Reserve in China.

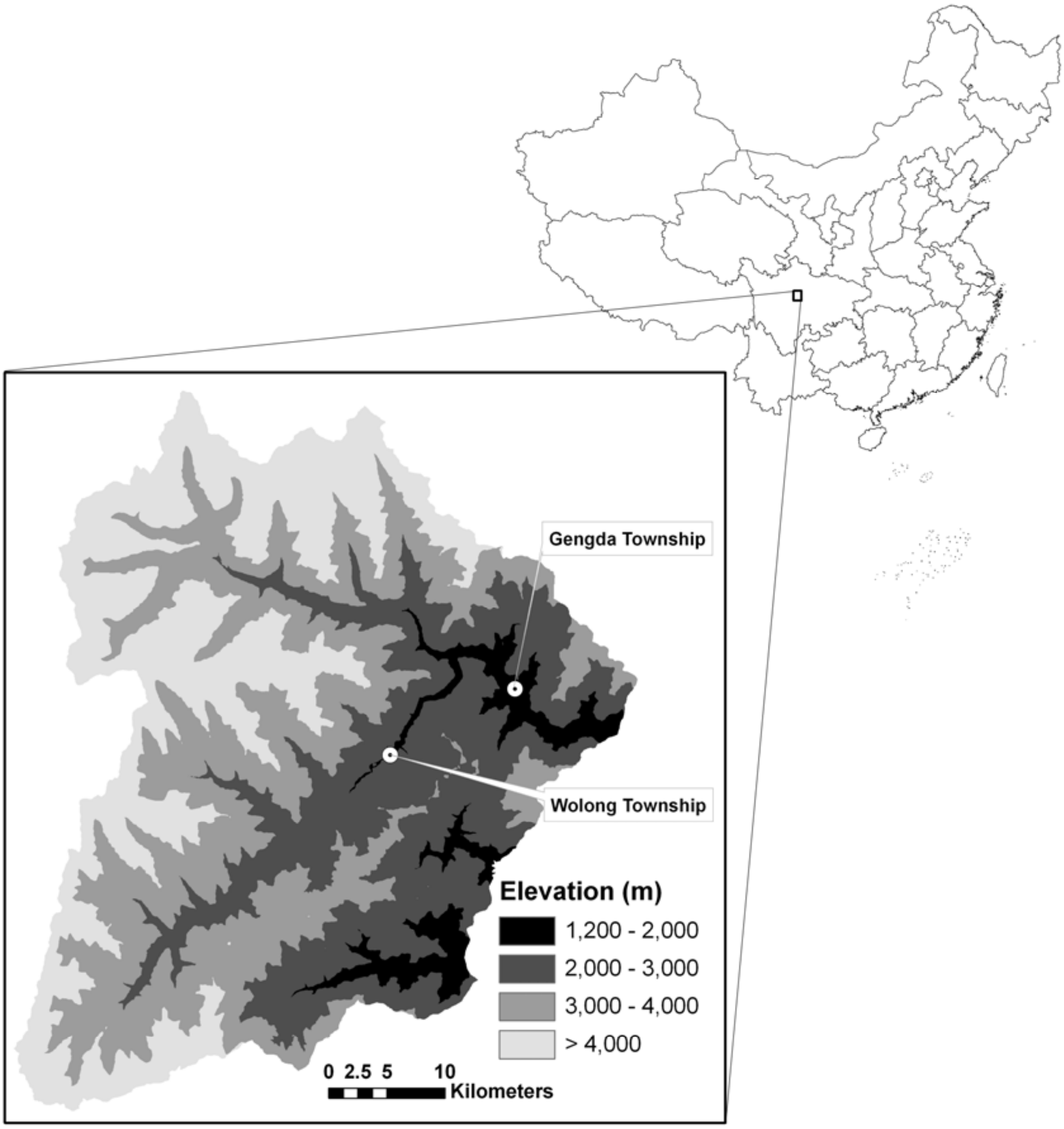


Figure 2. The effect of social capital on the environment as mediated by labor migration.

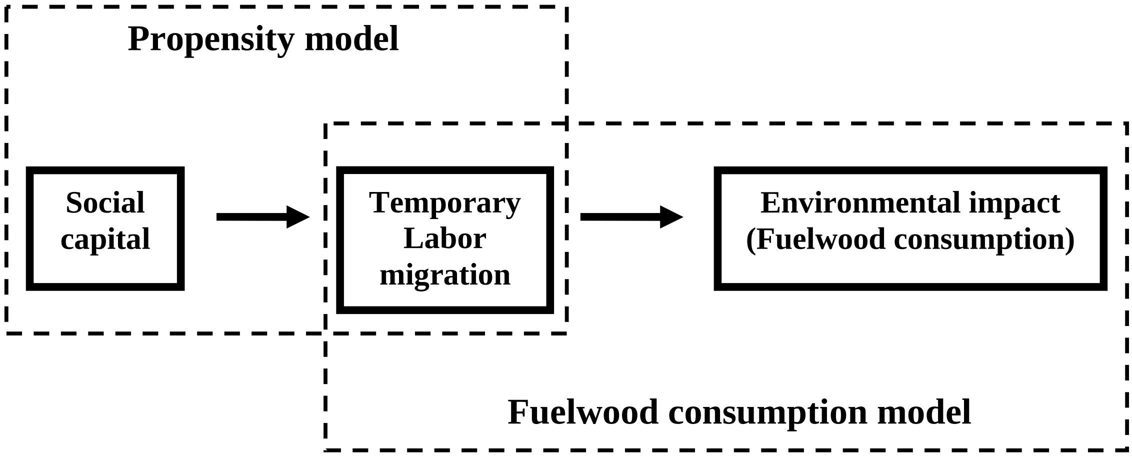
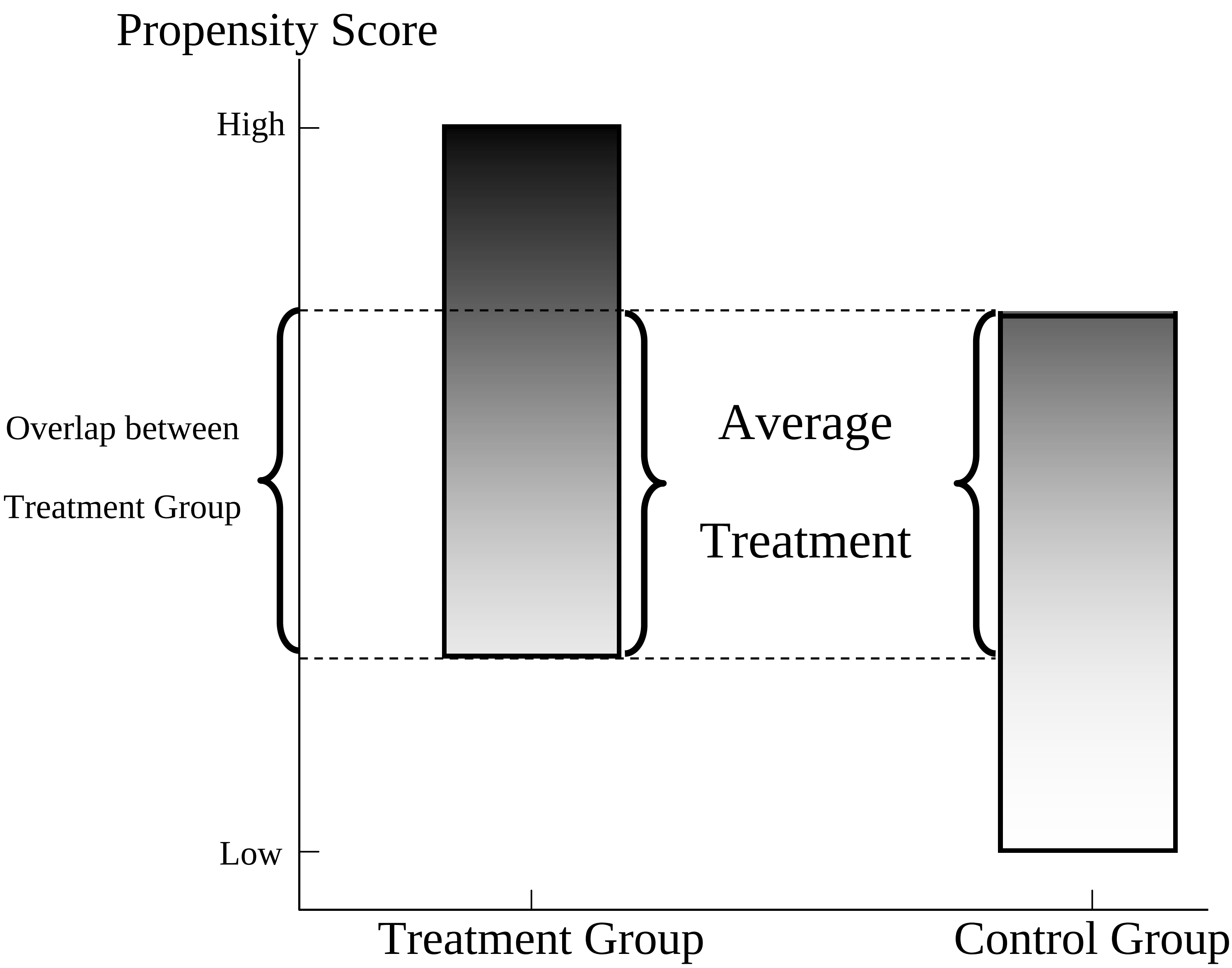


Figure 3. Overlap in propensity scores between treatment group and control group.



Appendix 1

Data and Methods:

Sampling methods

We chose household heads or the spouses of household heads as interviewees because they are usually the decision makers on household affairs and know the most about other household members' information (e.g., employment and income). From the government's household registration list containing 1156 households in all the groups in the reserve (groups are nested within villages within townships in rural China), households with temporary labor migrants were identified by group heads (farmers who are elected by their group members to coordinate some group affairs such as recruiting laborers for group infrastructure work). There were 138 households with temporary labor migrants in 2004. No eligible respondent in 7 of these households could be reached within 5 revisits and data from 2 households were not complete, which resulted in 129 households corresponding to 152 labor migrants. They worked in the construction (31.6%), transportation (11.8%), industry (18.4%), service (29.6%) and business (7.9%) sectors. About 74.3% of them worked in cities within the Sichuan province, and 25.7% of them worked in cities in other provinces in China. For the purpose of comparison, we also interviewed 215 households out of 223 households randomly selected from 1018 households that were not identified by group heads as households with labor migrants. Our overall response rate for interviews was 95%.

Propensity Weighting for Causal Inference

The weighting in (2) is informative for policy considerations because it reflects individual responses to incentives. If policies focus on changing incentives and resources for labor migration, then estimates of effects should focus on those most likely to respond to changes in policies: those who were employed outside the reserve but who had low propensity for doing so and, therefore, might not have become employed outside the reserve if there were fewer incentives for doing so; and those who were not employed outside the reserve but who had high propensity for doing so and therefore might respond to increases in incentives. Thus, the estimate using the weights in (2) is referred to as the effect of the treatment for people at the margin of indifference (EOTM) (Heckman 2005).

Propensity scores can also be used as a basis for matching or defining strata (Morgan & Harding 2006, Rosenbaum & Rubin 1983). We prefer the weighting approach because (1) the weighting scheme is relatively simple and intuitive; (2) estimates using the weights are easy to obtain (e.g., using weighted least squares) and can be implemented within the context of simple or more complex models; (3) because the estimand is a smooth function of the data (as in the weighted regression), bootstrapping techniques can be employed to calculate standard errors that reflect uncertainty in estimating the propensity; and (4) all subjects contribute to the analysis (though not equally, by definition). In fact, all matching estimators can be considered examples of weighting approaches (Morgan & Harding 2006), but only the Robins' approach we use here has been proven to improve the efficiency of estimation (Hirano et al. 2003). The greatest concern about weighting is that extreme weights could exert undue influence on the estimates. This is easily addressed by examining the distribution of weights and trimming extreme values.

Analytical Approach

After calculating the propensity weights, we confirm that the weights achieve balance on our covariates by testing for differences between households with and without temporary labor migrants using the weighted and unweighted data. Reduction in differences when employing the weights suggests that selection bias has been adjusted via the weights (Morgan & Harding 2006). A few determinants of labor migration that are not well balanced through the propensity weighting are also controlled as covariates in our regression analyses.

Quantifying the Robustness of the Inference

Our approach to quantifying robustness can be considered an extension of sensitivity analysis (Copas & Li 1997, Holland 1989, Robins et al. 2000, Rosenbaum & Rubin 1983, Scharfstein & Irizarry 2003). Sensitivity analyses consider a set of possible estimates given a broad set of alternative conditions. As in sensitivity analysis, we consider how violations of assumptions could affect estimates. But rather than reporting how violations of assumptions produce a range of estimates, we focus on exactly how much an assumption must be violated to invalidate an inference. As a result, the indices quantify the robustness of the original inference.

Classically, internal validity can be expressed in terms of confounding variables that are correlated with both the predictor of interest and the outcome (Shadish et al. 2002). We express the robustness of our inferences to these two relationships by employing the impact threshold (Frank 2000, Pan & Frank 2003). Frank (2000) defines the impact of a confounding variable on an estimated regression coefficient as $r_{vy} * r_{vm}$, where r_{vy} is the correlation between a covariate, *v*, and the outcome *y*; and r_{vm} is the correlation between *v* and *m*, the predictor of interest (for example, *m* is an indicator of the status of labor migration of the household -- see Figure S1).

To obtain the impact necessary to invalidate an inference, define $r^{\#}$ as a quantitative threshold for making inferences. Note that there is a direct relationship between *r* (the observed correlation between the predictor of interest and the outcome) and the statistical significance (t-ratio) of the predictor of interest (Cohen & Cohen 1983), $t = \frac{r\sqrt{d.f.}}{1-r^2}$, where *d.f.* is the degree of freedom in the regression analyses. In particular, defining $t_{critical}$ as the critical value of a t-distribution (e.g., for p $\leq$0.05), then $r^{\#} = \frac{t_{critical}}{\sqrt{d.f. + t^2}}$ defines a threshold based on statistical significance. That is, r_{my} (the correlation between the predictor of interest, *m*, and the outcome *y*) will be statistically significant if and only if it is greater than $r^{\#}$.

Given the definition of $r^{\#}$, a simplification of Frank (2000) shows that the original inference from a bivariate regression is invalid if $r_{vy} * r_{vm} > \frac{r_{my} - r^{\#}}{1-|r^{\#}|}$. Thus the quantity $\frac{r_{my} - r^{\#}}{1-|r^{\#}|}$ defines the impact threshold for a confounding variable for simple linear regression. That is, if the impact ($r_{vy} * r_{vm}$) of a confounding variable is greater than $\frac{r_{my} - r^{\#}}{1-|r^{\#}|}$ the original inference is not valid. The corresponding threshold for the multivariate case with covariates *z* is $\frac{r_{my|z} - r^{\#}}{1-|r^{\#}|}\sqrt{(1-r_{mz})^2(1-r_{yz})^2}$. Critically, because the impact is defined by correlation coefficients it can be readily understood by social scientists comfortable with correlation and the general linear model. This makes it an ideal complement to our use of propensity score weighting applied in a general linear model.

Results

Balancing Covariates Using the Propensity Score Weights

We tested for differences between those households with labor migrants and those without labor migrants on household level variables that are used in the propensity model. Note that we tested only for the household level characteristics because our next model of fuelwood consumption is defined at the household level. Test statistics with and without using propensity weighting as in equation (2) are presented in Table S1. Propensity weighting reduced the differences between the migration group and the non-migration group on almost all the household level variables except the Gengda township indicator. Land, non-migration income, and number of laborers in the household were not significantly different between the migration and non-migration groups after weighting. Although the availability of social ties outside of the reserve and that of ties to those holding leadership positions were still higher for the migration group than those for the non-migration group in the weighted analysis, there was less difference between the two groups after weighting. These two social ties covariates and the Gengda township indicator were still significantly different between migration and non-migration groups after weighting, and therefore were controlled in estimating the effects of labor migration on fuelwood consumption.

The Robustness of the Inference

We base the analysis of the robustness of the inference on the estimate of the average effect of labor migration, including non-migration income (coefficient = -1827, standard error = 242). The observed t-ratio of -7.55 translates to a correlation coefficient of -0.378 and, for a sample size of 344, the threshold for statistical significance ($r^{\#}$) is a correlation of -0.107. The corresponding impact threshold is -0.25. That is, to invalidate the inference the magnitude of the impact of an unmeasured confounding variable must be greater than 0.25. Furthermore, the magnitude of r_{vy} (the correlation between the unobserved confounding variable and fuelwood consumption) must be greater than 0.47 and the magnitude of r_{vm} (the correlation between the unobserved confounding variable and labor migration) must be greater than 0.54 to invalidate the inference.[9] Each component correlation is large by social science standards (Cohen & Cohen 1983). Moreover, these are zero-order correlations, assuming that the unmeasured confounder is uncorrelated with the measured covariates (Frank 2000). The relevant partial correlations (Cohen & Cohen 1983) from which the impact of an unobserved confounder would be constructed would be smaller than the zero-order correlations because of correlations with existing covariates.[10]

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[9] The zero order correlations are not necessarily equal when the impact is maximized with covariates in the model. If the component correlations do not take these exact values then the impact would have to be greater than .22 to invalidate the inference.

[10] Frank (2000) refers to this as absorption of the impact of an unmeasured confound by existing covariates.

Though the magnitude of the impact threshold for an unmeasured variable can be interpreted in terms of typical patterns of correlation in the social sciences, it is also helpful to compare the threshold to the impacts of measured covariates. Based on zero order correlations, the magnitude of the impact of the indicator of township (Gengda versus Wolong) is the largest of the existing covariates. Its impact is -0.037 and the sign is in the direction that reduces the negative effect of labor migration on fuelwood consumption. Thus the magnitude of the impact of an unmeasured confound necessary to invalidate the inference that labor migration affects the amount of fuelwood consumed in the household (0.25) would have to be more than six times greater than the magnitude of the strongest impact of the measured covariates, -0.037.

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Figure S1. The impact of a confounding variable on a regression coefficient.

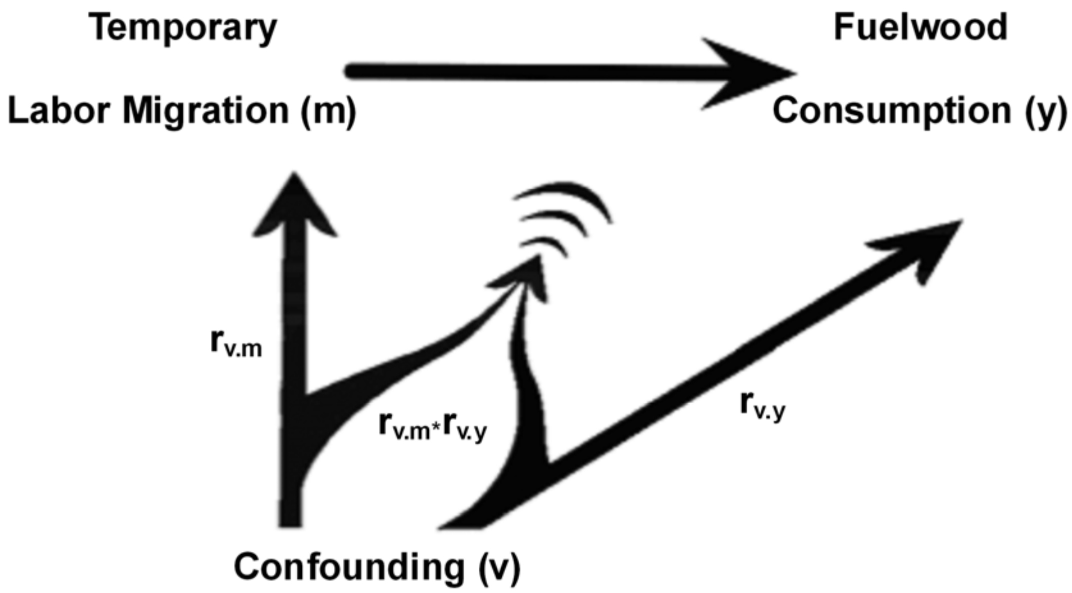

Table S1. Testing for balance between migration group and non-migration group with and without propensity weighting.

	Migration group (n = 129)	Non-migration group (n = 215)				
Variable	Mean (Standard deviation)		t-ratio [a] (unweighted)	χ^2 (unweighted)	t-ratio (weighted)	χ^2 (weighted)
Land	0.286 (0.153)	0.279 (0.152)	-0.41		-0.39	
Non-migration Income	9.098 (7.796)	10.945 (7.878)	2.11		0.37	
Laborers	3.093 (1.169)	2.386 (0.894)	-5.91		-1.58	
Gengda	0.698 (0.461)	0.540 (0.500)		8.39		10.30
Tie	0.814 (0.391)	0.572 (0.496)		21.10		15.95
Tie Leader	0.426 (0.496)	0.228 (0.420)		15.05		8.29

[a] Positive value indicates households with labor migrant(s) have lower mean than those without labor migrant(s).