Forest Protection and Rural Economic Welfare:

The case of Labagoumen Nature Reserve (China)

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Abstract:: This paper examines the *poverty-environmental degradation nexus* (PEDN), which asserts that poor households cause more environmental degradation than the non-poor. Using an original dataset on rural households living in a poor county in China, we investigate the relationship between households economic wealth and their firewood consumption, to test whether poverty is a source of forest degradation in China. We find a strong support for the poverty-environment hypothesis since households economic wealth is a significant and negative determinant of their fuelwood consumption. However, the PEDN hypothesis appears not to be due to an income effect, but to a substitution effect. Indeed, we find no support for income effect in firewood consumption among poorer households who do not use better substitutes to firewood, while income has a significant and negative impact on firewood consumption for richer households using substitutes as well as firewood.

Key words*:* poverty-environmental degradation nexus, natural resources protection, firewood collection, China.

JEL codes: Q23, Q28, I31, O12, C3.

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Introduction

In the context of the creation of a Nature Reserve in Labagoumen township (China), this paper examines the *poverty-environmental degradation nexus* (PEDN), which states that poor households rely more on environmental resources than the non-poor. A variety of reasons has been proposed in the literature for the PEDN (Arnold *et al.* 2003, Duraiappah 1996, 1998, Swane 2002, Wunder 2001), including a lower shadow cost of labour, lower preferences for expensive substitutes and stronger credit constraints. The PEDN has recently gained a large attention in the field of environment economics (Duraiappah 1998, Lopez 1998, Maler 1998) and has strong policy-related implications. In the context of the current Chinese environmental policy, it is particularly important to test the PEDN in rural China and evaluate its magnitude. Indeed, evidence of the PEDN has two main policy implications: *i)* poverty alleviation is a precondition for environment sustainability, and *ii)* implementing a nature reserve with a drastic limitation of access to common property resources might deepen poverty, since poorer households suffer more intensively from the deprivation of this type of resource.

In this paper, we test the PEDN on an original household dataset for 10 villages in Labagoumen township. The survey has been conducted in December 2001 at a very early stage of the implementation of the nature reserve. It provides information on 285 household living in poor agricultural areas and includes detailed information on household firewood collection and consumption. The main environmental issue in Labagoumen Nature Reserve is biodiversity conservation through forest protection. In the absence of both strong institutional incentives to protect forest resources, and secure property rights on forest resources, the implementation of a protection policy implies a restricted access to forests and firewood collection imposed on local populations. This policy may have strong implications on villages' economic activities as well as on households well-being.

The paper is organised as follows. Section 1 analyses the socio-economic context in which the Nature Reserve in Labagoumen has been established. More specifically, using descriptive statistics from our sample survey, we discuss the need for forest protection and biodiversity conservation in this county and we analyse the general dependence of households towards forest resources as well as energy consumption patterns in the villages. Section 2 presents a simple theoretical framework for firewood consumption in the presence of better but costly substitutes. It derives a relationship between households wealth and pressure upon forest resources. Section 3 evaluates the respective magnitude of substitution and income effects in firewood consumption decision at the household level, through the econometric estimation of firewood consumption equations as well as the estimation of choice models for the use of alternative sources of energy.

We find a strong support for the poverty-environment hypothesis on the whole sample since income is a significant and negative determinant of household fuelwood consumption. Poorer households thus rely more on environmental common property resources than the non-poor. However, we find no support for income effect in firewood consumption among poorer households who do not use better substitutes to firewood, whereas income has a significant and negative impact on firewood consumption for richer households using substitutes as well as firewood. This result is consistent with the theoretical model proposed in section 2 and corresponds to two distinct equilibria: *i)* below a certain income threshold, households do not use better substitutes to firewood such as coal or gas, and fuelwood consumption is entirely determined by households needs and does not depend on income, *ii)* above this income threshold, households use fuelwood as well as better energy substitutes and rising income leads to a higher degree of substitution and thus a decreasing fuelwood consumption.

The main policy implication of this paper is that forest protection in China cannot be implemented without strong support towards poor local communities to encourage diversification in energy consumption. Moreover, the implementation of a coercive policy as intended by the Chinese

government to forbid wood collection would result in aggravating poverty in vulnerable rural areas. Finally, our findings also indicate that besides economic measures, social habits also need to be changed in order to preserve forest resources and biodiversity.

Section 1 – Overview of Labagoumen Nature Reserve and its population

a. Labagoumen: a poor township in a rich municipality

Located in the north of Huairou county, Labagoumen township is the farthest northern village in Beijing municipality. The village government is 160 km away from Beijing city and 93 km from Huairou county seat. With 302 square kilometres, Labagoumen is the biggest township in Huairou county. It is composed of 15 administrative villages, in which 6,897 inhabitants were living (including a third of Manchu minority) in 1999.

In topographical terms, Labagoumen township is located in the mountainous part of Beijing municipality, with areas above 800 meters accounting for 44 percent of the total land area and a total difference in height between 1705 m and 424 m. It is characterised by a dry climate, and is situated in a semi-humid temperate zone with annual precipitations averaging 500 mm, the annual temperature averaging 7 to 9 degrees and for the coldest month (January) minus 12 to minus 8 degrees.

While belonging to the rich municipality of Beijing, Labagoumen township is a rather poor area, as compared to both neighbouring villages and provinces (Table 1). Indeed, in terms of per capita GDP, Labagoumen township is the second poorest township in Huairou county, with 5,668 yuan per capita in 1999. As illustrated in Table 1, Labagoumen township per capita income level is much lower than that of both Huairou county and Beijing municipality. Its per capita GDP is close to the one that can be observed in Inner Mongolia, a rather poor province in China (Démurger *et al.*, 2002).

Compared to Huairou county, Labagoumen township is dominated by farm activities, as indicate both value-added data and employment data. Indeed, the primary sector in Labagoumen township represented 27% of GDP in 1999 (against 18% in Huairou), of which 17% was due to agriculture and 4% to forestry. The agricultural sector employs more than half of the active population (against 44% in Huairou), while the industrial sector only accounts for 6% (against 15%) of the labour force.

b. Labagoumen Nature Reserve

Labagoumen Nature Reserve has been implemented in December 1999, under the responsibility of Beijing Municipality. Its main objectives are *i)* the protection of the largest natural forest in Beijing area, *ii)* biodiversity conservation, *iii)* the strengthening of the "green shelter" between Beijing city and northern arid areas, and *iv)* the protection of tourist resources in Beijing municipality. The Nature Reserve has been divided into three zones: *i)* a core area in which living and all economic activities are forbidden, *ii)* a buffer area in which building is forbidden but some economic activities are tolerated (non-wood products gathering, tree planting, etc.), and *iii)* an experimental area where local populations are allowed to live and engage in agricultural activities.

Besides the implementation of the Nature Reserve, a national logging ban has been imposed on natural forests following the great floods in 1998[1]. At the time of the field survey, households were thus facing the following restrictions*: i)* a logging ban imposed on timber as well as on fuelwood, *ii)* a pasture ban imposing cattle to remain in villages, *iii)* a restricted access to the core and buffer areas. However, in practice, most restrictions were not enforced. Indeed, most villagers were still collecting fuelwood as well as non-wood products in all areas of the Nature Reserve and cattle

1. This logging ban is known as the Natural Forest Protection Program (NFPP). For further details on this program coverage and achievements, see Xu *et al.* (2002) and Wang *et al.* (2003).

were grazing around forest areas.[2] The only sizable effect on rural population was the closure of local sawmills imposed by the national logging ban on natural forests[3].

In this context, we can thus consider that the situation in 2001 is an ex-ante observation concerning fuelwood collection prior to the enforcement of the Nature Reserve restrictions. In the following, we will address the question of the potential impact of these restrictions on local population livelihood.

c. Survey data

We use data from a household survey that was carried out in 10 villages (out of 15) in Labagoumen township in December 2001[4]. The survey provides detailed household and individual characteristics, energy consumption, firewood collection, and relation to forest resources data. Among the 10 hamlets surveyed, 5 belong to the Nature Reserve (see Map 1). Data collected cover 285 households, randomly drawn in the surveyed villages, and interviewed about their production and consumption activities for the year 2001.

Tables 2 and 3 provide descriptive statistics on households characteristics and energy consumption patterns. Households characteristics given in Table 2 show how poor Labagoumen township is. Indeed, education levels are very low, since the average number of years of education for the household head is less than 6 years, with the maximum being 13 years. This means that primary school is the average education level of household heads in the township, and no household reports a higher education level than senior high school. In terms of "nationality", more than one

2. Most villagers actually did not even know what were the restrictions imposed by the Nature Reserve.
3. One village in the survey (Maoshan) was particularly hit by this restriction since its major activity was timber production prior to the logging ban. Two sawmills employing around 30 persons have been closed down, with a total revenue loss estimated by the village leader as high as 250 000 yuans a year. Most laid-off workers were young and moved outside the village after the closure of the sawmills. Several small-scale sawmills in other villages have also been closed down with the logging ban, but their negative economic impact seems to be less important than in Maoshan. In Sunzhazi, the tourist heart of the Nature Reserve, according to the village leader, most laid-off workers started new activities in the transport or the tourist sector in the village, and earned higher wages.
4. The survey is the result of a collaborative effort involving the authors, Pascal Marty (CEFE, Montpellier), Yang Weiyong (CERDI), and a team from the Beijing University of Forestry headed up by Li Junqing and Cui Guofa.

third of the household heads belong to a minority, most of them being Manchu. Most households are engaged in agricultural activities, and only a few (13%) have members holding a non-agricultural residence permit (*hukou*). Hence, as already mentioned at the macro level, agriculture is the primary source of income for households. All but a very small percentage of households engage in farming (14 households over 285 do not declare any agricultural activity). Land per household ranges from approx. 0.03 ha to approx. 1.7 ha, and the mean cultivated farm size is less than half an ha.

Table 3 shows that firewood is a source of energy for heating and cooking for 70% of the households. The mean winter consumption of firewood per household is 337 kg. Given that the average size of household is 3.28, this means that annual per capita firewood consumption is around 103 kg/capita. Although 14% of households use only firewood for heating, nearly 60% also use substitutes. Among them, 90% use coal, 10% use straw, and only 3.5% and 1.8% use respectively gas and electricity. Hence modern fuel sources are rarely used in Labagoumen township, and the main substitute is coal. Firewood can thus be considered as a widely available basic energy source[5].

Less than 10% of the sample does not collect firewood. Among firewood collecting households, most of them report the principal collector being the household head (87%). The average number of collections per year is nearly 20, while the collection time is around 5 hours. Only 17% of the households report collecting firewood in forests, with the majority collecting either from hedges or isolated bushes. However, field observation reveals that firewood collection tends to concern young trees, on the edge of the forests, which is very detrimental to forest development and regeneration.

5 Indeed, fuelwood is available at walking distance from all villages in the survey and its only lower substitute is straw, which is always consumed jointly with fuelwood.

Section 2 – A simple theoretical framework for firewood consumption

a. The PEDN and firewood consumption: a brief survey of the literature

There has been a considerable debate on the impact of firewood collection on forest degradation and on its relationship with rural livelihood. As emphasized in Arnold *et al.* (2003), this question has received various attention throughout time. A great emphasis started in the 70s and early 80s motivated by studies showing that fuelwood consumption increases were threatening the sustainable development of forest resources (Eckholm 1975, Anderson and Fishwick 1984). Then followed a reappraisal of the magnitude of the phenomenon in the late 80s (Leach and Mearns 1988, Dewees 1989) and a "revival" of the issue since the beginning of the 90s with the growing attention to the link between environmental degradation and poverty (World Bank, 1991).

In a similar vein as the literature on the Environment Kuznets Curve (EKC) applied to forests degradation (Wunder 2001, Foster and Rosenzweig 2003[6]), the *poverty-environmental degradation nexus* (PEDN) is based on the idea that poor people threaten environment more strongly than richer people (World Bank 1992, Jalal 1993). However, as argued by Duraiappah (1996, 1998), the relationship between poverty and environmental degradation is of a multidimensional nature (including demographic, cultural and institutional factors) and there is at least a two-way causality. Indeed, if poor people depend strongly upon environmental resources, they may highly contribute to their degradation, but they may in turn suffer strongly from environmental degradation. This is especially the case for forest resources, upon which poor rural households are strongly dependent for firewood collection. On one side, firewood collection is one of the sources of forest degradation (Duraiappah, 1996, 1998), and on the other side, forest degradation makes it harder to collect firewood and hence impoverishes the poor.

6. Foster and Rosenzweig (2003) focus on the relationship between the increase in wood demand and forest cover in the curse of economic development. They actually question the environment Kuznets Curve (EKC) for forests, and find no strong evidence on the relationship between income and forest cover.

The main economic dimensions behind the relation between poverty and forest degradation through fuelwood collection are the following: income, opportunity costs, market imperfections, institutional weaknesses and credit constraints (preventing poorer households from shifting to higher income and less environment intensive occupations)[7]. Our main concern here is to address the question of the PEDN issue in China by testing the dependence of fuelwood consumption to income and opportunity costs. Indeed, the PEDN predicts that rising income leads to a lower fuelwood collection and thus less forest degradation. However, some works on the determinants of firewood consumption find no or positive effects of income on fuelwood consumption (Mekonnen 1999, Gundimenda and Köhlin 2003) and recent works on firewood collection behaviour have also questioned the PEDN hypothesis (Bardhan *et al.* 2002, Zwane 2002). Using household data on Nepal rural areas, Bardhan *et al.* (2002) show evidence against the PEDN. Their results indicate that fuelwood collection is positively related with income and negatively related with the opportunity cost of time as shown by the negative effect of education and nonfarm employment opportunities on fuelwood consumption.

In the case of Labagoumen township, as in most protected forest areas in China, the most important sources of forest degradation are local population fuelwood collection and cattle grazing. In this respect, studying firewood consumption patterns is a key issue in terms of forest resources protection. Moreover, China's forest protection measures consist mainly in imposing logging bans and access restrictions to forest resources, which directly affect the well-being of poorer households in rural areas. In the following, we propose a simple theoretical framework illustrating potential mechanisms underlying the PEDN, which is also consistent with opposite results found in the literature.

b. A simple theoretical framework: firewood consumption in the presence of a better substitute

7 See Arnold *et al.* (2003), Cooke St. Clair *et al.* (2002), Duraiappah (1998), Mekonnen (1999), Wunder (2001).

Firewood collection in poor rural areas such as Labagoumen township has three strong characteristics: *i)* firewood markets are scarce or non-existent, *ii)* the monetary price for firewood collection is low[8], and *iii)* the main cost of firewood is the opportunity cost of time spent collecting firewood. In this respect, firewood consumption differs from the consumption of substitute sources of energy such as coal or gas which are only available at market prices.

In order to provide a simple analytical framework, we make the following three assumptions:

A1: Households consume three types of goods : *i)* firewood, *ii)* a better substitute to firewood (such as coal or gas), and *iii)* a composite consumption good.

A2: Since there is no market for firewood in Labagoumen township, we consider that firewood collection costs include a direct monetary cost as well as an opportunity cost corresponding to the potential income loss induced by the time dedicated to firewood collection.

A3: Energy substitutes to firewood are "better goods" compared to firewood, so that consumption of alternative energy sources only appears above a certain income threshold.

These three assumptions can be expressed by the following utility maximisation program for rural households :

$$\begin{cases} \text{Max } \left[U = C_1^{\alpha}(C_2 + a)^{\beta}C_3^{\gamma}\right] \\ \text{u.c. } p_1C_1 + p_2C_2 + p_3C_3 = Y - (\delta Y)C_1 \end{cases} \quad (1)$$

C_1 represents firewood consumption, C_2 represents the consumption of energy substitutes, C_3 represents the consumption of a composite good and Y represents potential household income[9].

p_2 and p_3 represent monetary prices for goods *2* and *3* and p_1 represents the direct monetary cost of the collection of one unit of firewood.

δY represents the opportunity cost of time devoted to the collection of one unit of firewood.

8. This cost includes transportation costs and tools costs.
9. Potential income here refers to total income if no time is devoted to firewood collection.

It should be finally noted that the term ($C_2 + a$) in the utility function is a simple way of allowing for assumption 3 within a Cobb-Douglas framework as shown by figure B1, Appendix B.

This very simple and quite standard formulation leads to the following results[10].

Case 1: Firewood is the only energy source consumed

A first maximisation result corresponds to the corner solution for which C_2=0. In this case, households only consume firewood and the composite consumption good, and optimal firewood consumption takes the following form:

$$C_1^* = \frac{\alpha / (\alpha + \gamma)}{(\delta + p_1 / Y)} \qquad (2)$$

This result shows that for poorer households, which consume only firewood, firewood consumption is an increasing function of potential income. This corresponds to a standard income effect for consumption of a normal good.

It should be noted however that the magnitude of this income effect strongly depends on the level of p_1. Indeed, in the context of rural households living close to the forest, direct cost of firewood collection are very low and, in most cases, even null. In the case where there is no direct cost and the only cost of firewood is the opportunity cost, equation (2) becomes:

$$C'^*_1 = \frac{\alpha}{\delta(\alpha + \gamma)} \qquad (2')$$

which shows that there is no relation between potential income and firewood consumption.

10. Detailed calculations are provided in Appendix C.

Case 2: Firewood is consumed jointly with an alternative energy source

For sufficiently high income levels[11], the maximisation of household utility leads to a positive consumption of the alternative energy source (C_2>0). In this case, households optimal firewood consumption takes the following form:

$$C_1^{**} = \frac{\alpha}{(\delta + p_1 / Y)(\alpha + \beta + \gamma)} + \frac{\alpha a p_2}{(\delta Y + p_1)(\alpha + \beta + \gamma)} \qquad (3)$$

The first term of equation (3) corresponds to the usual income effect: consumption rises with income. The second term corresponds to a substitution effect: consumption of firewood decreases with income due to the increasing opportunity cost of time inducing a higher degree of substitution between firewood and the alternative energy source C_2.

As for case 1, results are a little different if there is no direct cost for firewood collection (p_1=0). In this case, equation (3) becomes:

$$C_1^{**} = \frac{\alpha a p_2 / \delta(\alpha + \beta + \gamma)}{Y} \qquad (3')$$

Firewood consumption is thus a decreasing function of income. Indeed, in the absence of direct cost, there is no income effect and the only remaining effect is the substitution/opportunity cost effect.

c. Conclusion on the PEDN hypothesis

This simple illustrative framework shows that the PEDN may be a little more complicated than the usual assertion that poorer households rely more on environmental common property resources than the non-poor. Indeed, it is most commonly observed that poorer households do not substitute firewood for alternative energy sources. In this case, within this poorer part of the population, our model shows that a positive correlation may be observed between income and firewood consumption. Moreover, we show that this relationship strongly depends on direct

monetary costs associated with firewood collection. In this respect, a poor household living next to forest resources may show not relation whatsoever between income and firewood collection, whereas the same household living far from the forest will. In the case of Labagoumen, all households live at walking distance from the forest, which pleads for very low direct costs for firewood collection.

In poor regions, it is also commonly observed that even households using alternative energy sources continue to consume firewood. Our simple model illustrates the substitution pattern between firewood and better but more expensive alternative energy sources and shows that two effects are at stake: *i)* the income effect tending to increase firewood consumption with rising income and *ii)* the substitution effect tending to decrease firewood consumption as rising income allows for a larger use of alternative energy sources. The respective magnitude of these two effects depends on prices, households characteristics and preferences as well as on direct monetary costs associated with firewood collection. We show that the lower these costs are, the stronger is the substitution effect compared to the income effect. In the extreme case where households live next to forest resources, as it is the case in Labagoumen township, substitution will be the only effect and a negative correlation between income and firewood consumption is expected, pleading in favour of the PEDN hypothesis.

Contrasting results found in the literature on the PEDN hypothesis can also be interpreted within this framework. Indeed, Gundimeda and Köhlin (2003), on Indian data, find that fuelwood is a normal good for poorer households whereas it is an inferior good for richer households in urban areas. This observation would correspond to case 1 (equation 2) for poorer households with income below the substitution threshold, and to case 2 (equation 3) for richer households, with a substitution effect overcompensating the income effect. In the same line, Bardhan *et al.* (2002) evidence against the PEDN can be analysed within the proposed framework since Nepalese households concerned by

11. Threshold calculations are given in Appendix C.

the survey are very poor and live in "villages fairly remote from modern transport and communication" (p. 16). The real cost of better substitutes to fuelwood is thus very high which in turns entails that the substitution income threshold remains in the majority of cases above household income[12].

Section 3 – Firewood consumption in Labagoumen: income versus substitution effect

a. Constructing a wealth index

To test the PEDN hypothesis, we need information on the level of income or wealth at the household level. Although our survey includes information on household income, many answers happen to be inconsistent or subject to large measurement errors. However, our survey includes two sets of questions that can be used to construct a wealth composite index, computed as a linear combination of household assets indicators through principal components analysis (Filmer and Pritchett 1998, 1999). First, households were asked to report about ownership of various assets, including bicycle, motorcycle, colour TV, black and white TV, radio, refrigerator, washing machine or electric fan. Second, questions were asked about housing characteristics, namely the source of drinking water, the number of rooms, the surface of the dwelling, etc.

In order to rank households by their economic wealth, we aggregated these variables into a composite index, weighted through principal components techniques, as done in Filmer and Pritchett (1998, 1999). We selected 9 indicators reflecting the level of household assets and housing characteristics: the number of rooms in dwelling, the dwelling size, the access to running water, the ownership of a bicycle, a motorcycle, a colour TV, a radio, a refrigerator and a washing machine.

The results of the principal components analysis are given in Appendix D. They give the eigenvector estimates, as well as summary statistics for each variable. We only use as a wealth

12. Only 3% of households in their survey used better substitutes to fuelwood and nearly one third used lower substitute

indicator the first principal component (with an eigenvalue of 2.5), which accounts for 28 per cent of the variance in our indicators.

b. Testing the PEDN on firewood consumption

Regressions reported in Table 4 provide estimation results on the relationship between household economic wealth and firewood consumption in the township of Labagoumen, as well as additional evidence on the determinants of firewood consumption. Equations 1 to 4 are estimated through standard OLS since no censoring is involved. Indeed, all households report a positive consumption of firewood.

The determinants of fuelwood consumption can be grouped into three categories: household needs, household preferences and economic characteristics of firewood consumption.

A first set of explanatory variables includes household needs indicators such as the household size, and the use of alternative sources of energy for heating. The estimated specification for the household size (measured in adult equivalent) shows that the effect of household size on firewood consumption is concave. This result is consistent with expectations, given the fact that, as the number of members in a household grows, the additional member benefits from the firewood consumption of other members (for both heating and cooking). For households who, besides firewood, also use alternative sources of energy for heating (mainly coal and to a small extent, gas and electricity), wood consumption is obviously less important than for non-substituting households. The negative and significant coefficient associated with the consumption of other energy sources for heating suggests that the diversification in heating sources helps reducing the consumption of firewood, other things being equal.

A second set of explanatory variables includes household preferences indicators such as age, education, minority status or links with other regions. Among these indicators, the only significant

to fuelwood such as cow dung, leaves or straw for heating and cooking.

variable is the household average age. The basic idea for introducing the household average age is that older people may tend to perpetuate traditions more than younger households and may thus tend to use firewood more intensively. Indeed, Table 4 indicates that the household average age has the expected positive impact on firewood consumption.

A final set of explanatory variables represents the economic characteristics of firewood consumption. Three important factors should be accounted for: household wealth, the opportunity cost of firewood collection and wood prices. Since there is no market for wood in Labagoumen, we focus only on the first two factors, proxied respectively by our wealth composite index, and by he fraction of non-agricultural Hukou in an household and the frequentation of forests for other purposes than collecting firewood. As suggested by the estimated negative coefficient, the higher the percentage of non-agricultural Hukou in an household, the greater the opportunity cost of collecting firewood. Moreover, concerning the frequentation of forest for other purposes than collecting firewood, we also expect that, the more households go to forests, the more they will tend to also collect firewood and use it intensively. This hypothesis is corroborated by the positive estimated coefficient for the whole sample (equations (1) and (2)).

Finally, concerning the relationship between wealth and firewood consumption, our estimations show different interesting results. First, as indicated in Equation (1), in the case of Labagoumen township, we show evidence in favour of the PEDN hypothesis. Indeed, the coefficient associated with the wealth index is negative and significant. Moreover, when we add an interactive term between wealth and firewood consumption as the only source of heating, Equation (2) indicates that the PEDN hypothesis is not due to an income effect (in terms of opportunity cost) but to a substitution effect (that is, to richer households, able to substitute for heating). Equations (3) and (4) further illustrate this finding, since they estimate the firewood consumption determinants for two different samples: households using only wood for heating on one hand, and households using substitutes on the other hand. Equation (3) indicates that there is no income effect for the poorest

households, while equation (4) shows evidence in favour of the PEDN hypothesis for substituting households. More precisely, equation (3) can be related to case 1 derived by our simple theoretical framework presented in section 2. In the case of Labagoumen, households are living next to forests resources, which means that firewood collection direct costs are very low. Our results show that the opportunity cost and the income effect cancel each other out, which is consistent with the model presented in section 2. Equation (4) relates to case 2 in section 2 and is consistent with the theoretical discussion in the sense that the substitution effect is important. Once again, these results correspond to the very low direct costs in firewood collection.

Our results have several policy implications. Contrary to Bardhan *et al.* (2002), they imply that there should be a positive effect on forest resources due to the enrichment of the population. However, the positive effect of the PEDN hypothesis strongly depends on substitution, and thus on the decision to use alternative sources of energy. This means that to protect forest resources, it is important to encourage substitution, given that getting richer decreases wood consumption. In other words, it means that two effects are at work: a static one, due to substitution, and a dynamic one, amplified by the growth in income.

c. The determinants of substitution choice

The preceding section shows that the key issue of firewood collection in Labagoumen is household decision to use alternative sources of energy for heating (substitution). We further investigated this point by estimating substitution choice equations using both a Probit model and an ordered Probit model on the substitution choice[13] (no substitution / partial substitution / total substitution). Results reported in Table 5 first confirm the importance of wealth as a main determinant of substitution choice. Moreover, we find that the use of alternative costly sources of energy for heating also depends significantly upon the average education level of adult members.

13. Substitution is to be understood here as substitution to a better energy source such as coal or gas.

This reflects differences in household preferences since more educated people tend to valuate the use of cleaner and healthier energy sources. A second set of substitution choice determinants concerns the household needs for efficient heating, as shown by the effect of the fraction of children and elderly in the household. Finally, opportunity costs are also at stake since the fraction of elderly can also reflect a higher human cost for firewood collection, leading to a decreasing comparative cost of alternative energy sources.

Conclusion

Since the implementation of the NFPP logging ban, deforestation has been mostly controlled in China's natural forests. However, forest degradation remains an important issue since poor rural populations are still collecting firewood and grazing cattle around forests. The Chinese authorities answer to this question mostly consists in imposing coercive measures on local population such as the interdiction to cut trees for fuelwood, a restricted access to forest resources and the interdiction of grazing cattle. Our study on Labagoumen before the formal enforcement of measures on firewood collection provides strong evidence in favour of the PEDN and shows that local poorer populations are strongly dependent upon forest resources. Imposing coercive measures without any strong accompanying measures would thus certainly lead to a deepening of rural poverty. Moreover, forests resources are actually suffering from the current *status quo* since tolerated fuelwood collection concerns in many cases young trees growing at the edge of forests, which is certainly much more detrimental to forest resources than a sound management of fuelwood resources.

The main policy implications of our work are thus twofold. First, in order to preserve forest resources and biodiversity, forest protection in China should be implemented with strong emphasis on poor local communities fuelwood consumption and collection behaviour. It should aim at encouraging diversification in energy consumption through a greater local availability of low cost

substitutes such as biogas as well as by changing local population habits concerning cooking and heating. Second, since poorer households are strongly dependent upon forest resources, the implementation of a coercive policy as intended by the Chinese government to forbid wood collection would result in aggravating poverty in vulnerable rural areas. Finally, the current *status quo* consisting in the absence of enforcement of coercive rules is detrimental to forest resources and Nature Reserve rules based on a sound local management of fuelwood resources would undoubtedly be preferable.

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Table 1 – Per capita income comparisons, 1999 (yuans)

	Per capita GDP in 1999	Total population in 1999
Labagoumen township	5,668	6,897
Huairou county	11,185	188,445
Beijing municipality	19,846	12,570,000
Hebei province	6,932	66,140,000
Inner Mongolia	5,350	23,620,000
Liaoning province	10,086	41,710,000
Jilin province	6,341	26,580,000
Anhui province	4,707	62,370,000
Guangdong province	11,728	72,700,000

Sources: *China Statistical Yearbook*, 2000; *Beijing shi Huairou xian shehui jingji tongji nianjian*, 1999.

Table 2 – Households summary statistics

Variable	Number of observations	Mean	Standard deviation	Minimum	Maximum
Household size	285	3.28	1.08	1	6
Household head average years of schooling	285	5.80	3.37	0	13
Fraction children	285	0.12	0.16	0	0.66
Fraction elderly	285	0.15	0.28	0	1
Household head non-Han nationality	285	0.38	0.49	0	1
Fraction non-agriculture labour	285	0.05	0.15	0	1
Firewood consumption during winter (kg)	269	337.36	194.77	35	1120
Collection time (hours)	263	5.26	2.12	1	15
Average number of firewood collection in a year	259	19.38	23.88	1	200

Table 3 – Energy consumption and firewood collection

Variable	Number of households	Percentage of households
Energy consumption		
Wood for heating only	40	14.04%
Wood for heating and other (such as cooking)	198	69.47%
Other energy sources for heating	170	59.65%
Firewood collection		
Collecting firewood	263	92.28%

Table 4 – Household firewood consumption determinants

Variable	Eq. (1) Total sample	Eq. (2) Total sample	Eq. (3) Wood for heating only	Eq. (4) Others
Wealth	-19.78***	-18.34**	-21.76	-22.02***
	(7.23)	(7.52)	(16.29)	(7.51)
Wealth*Firewood consumption		-4.99		
		(16.43)		
Household average age	3.58***	3.61***	5.26***	2.62**
	(0.99)	(0.97)	(1.81)	(1.16)
Household size	682.86***	690.09***	828.70**	652.52***
	(137.06)	(141.86)	(373.2)	(132.84)
(Household size)²	-148.39***	-150.05***	-179.17*	-145.57***
	(40.33)	(41.7)	(108.8)	(40.35)
Use of other energy sources for heating	-55.39**	-54.4**		
	(24.56)	(25)		
No wood consumption for heating				-61.73**
				(29.87)
Fraction of non-agricultural Hukou	-165.91***	-164.44***	-285.91***	-115.96**
	(51.16)	(51.12)	(96.14)	(59.38)
Go to forests for other purposes	48.37*	48.54*	70.30	33.18
	(25.12)	(25.14)	(47.06)	(29.3)
Constant	-515.04***	-525.42***	-751.41**	-467.54***
	(150.95)	(153.66)	(358.2)	(161.79)
Number of observations	268	268	103	165
R^2	0.1526	0.1529	0.1582	0.1315
Adjusted R^2	0.1298	0.1268	0.1056	0.0928

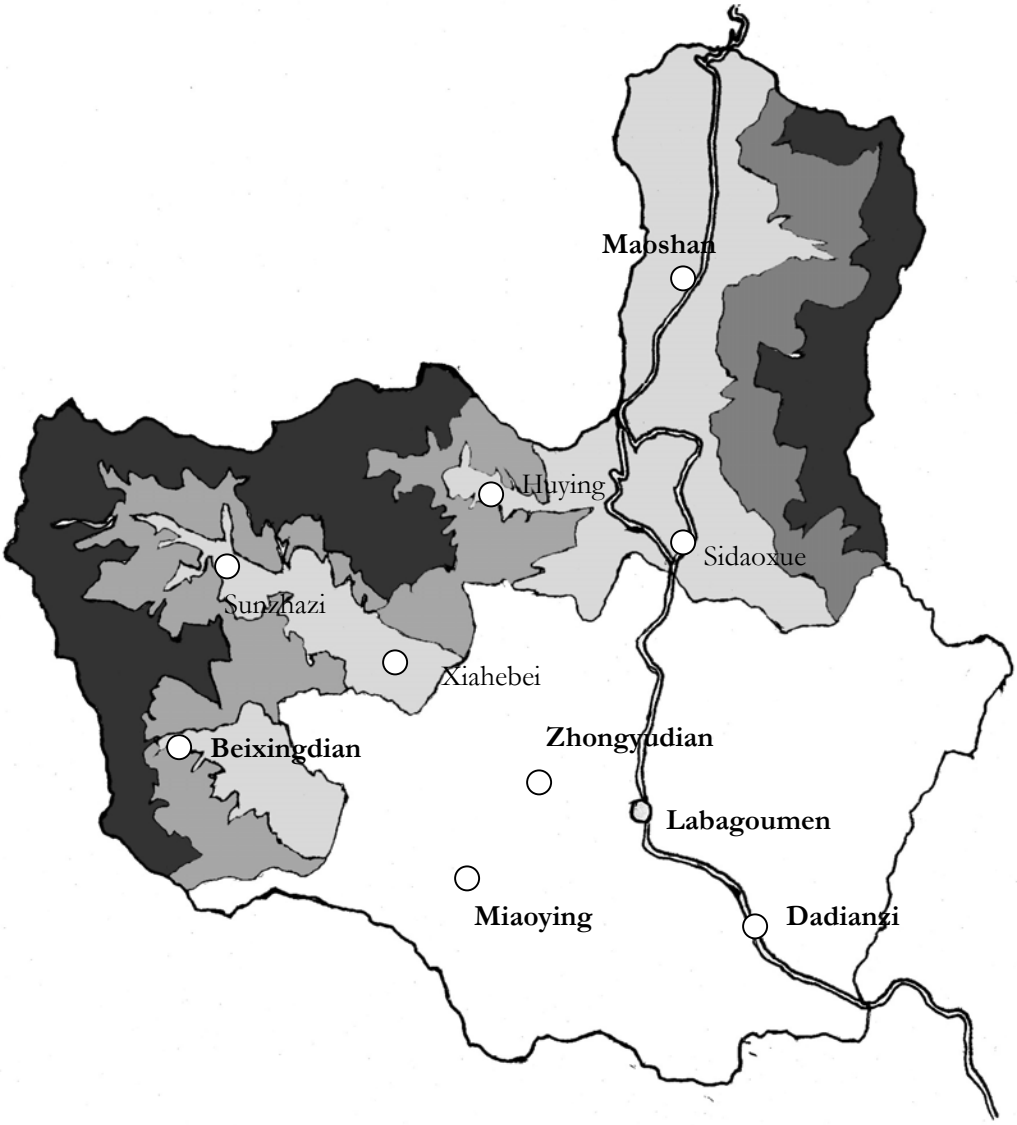
Notes: The dependent variable is the volume of winter firewood consumption. Robust standard errors are given between brackets.
*: significant at 10% level, **: significant at 5% level, ***: significant at 1% level.

Table 5 – Determinants of the use of alternative energy sources

Variable	Use of alternative energy sources for heating (Probit)	Use of alternative energy sources for heating (Ordered Probit)
Wealth	0.17***	0.08*
	(0.06)	(0.05)
Household size	-0.29	-0.27
	(0.30)	(0.25)
Average education level of adult members	0.14***	0.10***
	(0.03)	(0.03)
Fraction of children	0.68	0.87**
	(0.53)	(0.46)
Fraction of elderly	0.69**	0.51*
	(0.32)	(0.28)
Constant	-0.06	-
	(0.53)	
Number of observations	284	284
Log-likelihood	-173	-279
Pseudo-R^2	0.09	0.04

Notes: The dependant variable for the ordered Probit estimation is: "use only firewood for heating" / "use firewood as well as substitutes" / "use no firewood for heating".
*: significant at 10% level, **: significant at 5% level, ***: significant at 1% level.

Map 1 – Labagoumen Nature Reserve and surveyed villages



Notes: Non-official map. The different villages are located approximately. The different colours represent the three different zones (core / buffer / experimental) in the Nature Reserve.

Appendix A – Administrative division of Beijing Municipality (2001)

Region	Town	Township	Urban Sub-district Office	Neighbourhood Committee	Village Committee
City areas			**35**	**797**	
Dongcheng			10	232	
Xicheng			10	223	
Chongwen			7	156	
Xuanwu			8	186	
Near Suburbs	**2**	**36**	**70**	**2,285**	**331**
Chaoyang		24	22	432	163
Fengtai		4	16	644	69
Shijingshan			10	135	11
Haidian	2	8	22	1,024	88
Outer Suburbs	**82**	**7**	**24**	**638**	**2,400**
Mentougou	9		4	136	177
Fangshan	14	6	7	133	463
Tongzhou	10	1	4	146	480
Shunyi	19		3	35	425
Changping	16		3	135	312
Daxing	14		3	53	543
Counties	**55**	**9**	**5**	**191**	**1,279**
Pinggu	15	2	2	36	273
Huairou	***12***	***2***	***2***	***31***	***287***
Miyun	17	1		66	344
Yanqing	11	4	1	58	375
Total	**139**	**52**	**134**	**3,851**	**4,010**

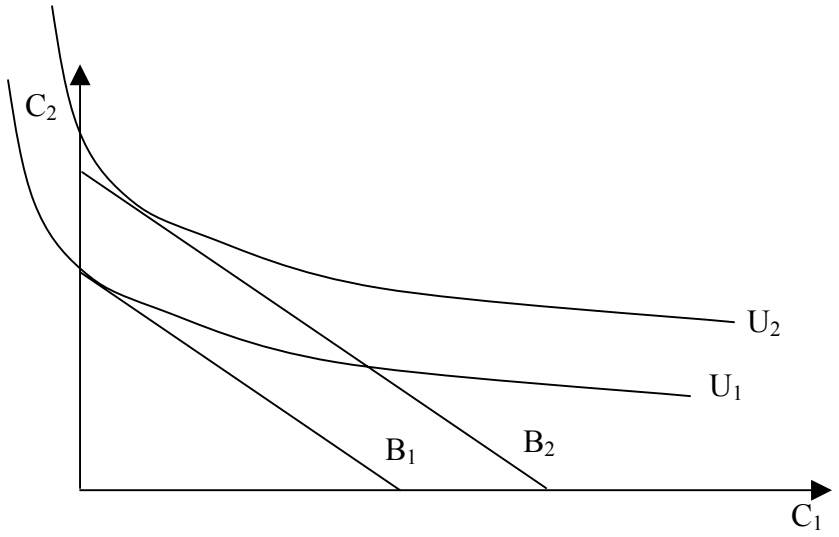
Notes: Labagoumen township is one of the 2 townships under Huairou county.

Appendix B – Alternative energy sources consumption beyond an income threshold

Section 2 defines households utility function as : $U = C_1^{\alpha}(C_2 + a)^{\beta} C_3^{\gamma}$

This formulations allows for consumption of a better good C_2 (here alternative energy sources such as coal or gas) beyond a certain income threshold. Visually, the corner solutions where $C_2 = 0$ can be represented for any level of C_3 in the (C_1 , C_2) plan as follows.

Figure B1



Where budget constraint B_1 corresponds to the corner solution $C_2 = 0$, whereas higher income budget constraint B_2 corresponds to a positive consumption of C_2.

Appendix C – Utility maximisation results

The utility maximisation program used in section 2:

$$\begin{cases} \text{Max } \left[U = C_1^{\alpha}(C_2 + a)^{\beta}C_3^{\gamma} \right] \\ \text{u.c. } p_1C_1 + p_2C_2 + p_3C_3 = Y - (\delta Y)C_1 \end{cases} \quad (1)$$

leads to the following results:

Case 1 : if $Y < ap_2\left(\frac{\alpha+\beta+\gamma}{\beta} - 1\right)$

$$\begin{cases} C_1^* = \dfrac{\alpha/(\alpha+\gamma)}{(\delta + p_1/Y)} \\ C_2^* = 0 \\ C_3^* = \gamma/(\beta+\gamma)\dfrac{Y}{p_3} \end{cases}$$

Case 2 : if $Y \geq ap_2\left(\frac{\alpha+\beta+\gamma}{\beta} - 1\right)$

$$\begin{cases} C_1^{**} = \dfrac{\alpha}{(\delta + p_1/Y)(\alpha+\beta+\gamma)} + \dfrac{\alpha a p_2}{(\delta Y + p_1)(\alpha+\beta+\gamma)} \\ C_2^{**} = \dfrac{\beta Y}{p_2(\alpha+\beta+\gamma)} + \dfrac{\beta a}{(\alpha+\beta+\gamma)} - a \\ C_3^{**} = \dfrac{\gamma Y}{p_3(\alpha+\beta+\gamma)} + \dfrac{a\gamma p_2}{p_3(\alpha+\beta+\gamma)} \end{cases}$$

Appendix D –Principal components analysis

Eigenvector and summary statistics for variables entering the computation of the first principal component for the wealth indicator:

Variable	Eigenvector	Mean	Standard deviation
Number of rooms in dwelling	0.421	3.71	1.49
Dwelling size	0.473	67.44	30.43
Running water	-0.014	0.77	0.42
Own bicycle	0.148	0.786	0.411
Own motorcycle	0.279	0.168	0.375
Own colour TV	0.362	0.656	0.476
Own radio	0.239	0.354	0.479
Own refrigerator	0.407	0.186	0.390
Own refrigerator	0.407	0.186	0.390

Notes: Except the number of rooms, the dwelling size and the arable land are, variables take the value 1 if "yes", and 0 otherwise.