

## A Appendix A: Data

### A.1 Survey Data

As described in the text, the data used in this paper stems from household surveys from 10 countries around the world, which were selected because they included questions on payments to local public good provision. Since each of the surveys is somewhat different in terms of sampling and questionnaire design, this section briefly describes each of these surveys one by one, including details on the informal tax question, sampling design, and the definition of a community used for community fixed effects. Since the derivation of VAT tax rates is somewhat more involved, Section 2 separately discusses the construction of implied VAT rates in each country in more detail.

In constructing the data, we use several normalizations to standardize the data. To standardize units of time (e.g, for labor contributions) between surveys, we assume that each “day” worked is equivalent to 6 hours worked, and that there are 260 working days per year. When including “village” fixed effects, we use the smallest geographic unit available in the data. When the smallest geographic unit includes both urban and rural areas, we interact the geographic unit with an urban/rural dummy, so that each “village” is entirely rural or entirely urban. We convert all local currency units to 2000 PPP dollars after obtaining the exchange rate by dividing each country’s GDP in local currency units for that year by the GDP in PPP constant 2000 international dollars. This data is available in the World Bank World Development Indicators.

All our surveys (with exception of Ethiopia) provide a household level weight variable to account for the sampling procedure. We used these weights in calculating the descriptive statistics (Table 3), as well as in all our regression analysis.

#### A.1.1 Albania

We use the Albanian Living Standards Measurement Survey, conducted in mid-2005 by the Living Standards Unit of Albania’s National Statistical Institute, with the technical assistance of the World Bank. This survey is the fourth round of a series of LSMS, which began in 1996. The survey covers 3,840 households in urban and rural areas and is nationally representative.

Our estimation of payments is based on questions 12 and 13 of the Social Capital module of the household questionnaire. These questions ask about the payment of the entire household and cover “participation in any activities, in which people come together to do some work for the benefit of community.” Conditional on a positive response to this question, the following question asks about “how many times in the past year” the household has participated in such activities. Each “time” was counted as a working day.

Communities are defined as villages, which are subgroups of districts and municipalities.

#### A.1.2 Ethiopia

We use the Ethiopia Rural Household Survey, which covers 1,507 rural households. This survey was been conducted by the International Food Policy Research Institute in 1997 as the fourth round of the series of household surveys started in 1989.

We examine questions from the Community Work section of the household questionnaire. The first question asks whether the “household engaged in community work in the last 12 months.” The following question inquires about “how many days the household engaged in community work.”

The survey documentation notes that "... these data are not nationally representative. However, they can be considered broadly representative of households in non-pastoralist farming systems as of 1994."

Communities are defined as peasant associations, which are subgroups of regions and woredas (subdistricts).

### **A.1.3 Guatemala**

We use the Guatemala Living Standards Survey (Encuesta Nacional Sobre Condiciones de Vida), which covers 8,940 household in rural as well as urban areas. This nationally representative survey was conducted in 2000 by the Guatemalan National Statistics Institute, with the technical and financial assistance of the World Bank and the Inter-American Development Bank.

We used question II.A.1.1, which asks whether households "participate in the collective construction of community works (roads, schools, etc)." Two other questions, II.A.1.h and IX.E.3, which asked respectively about cash or in-kind donations and the amount of hours contributed per household, were not used. The decision to exclude those is due to the ambiguity of the former and the fact that the recall period of the latter was only one day.

Communities are defined as sectors, which are subgroups of regions, departments, and municipios.

### **A.1.4 Indonesia**

We use Wave I of the Indonesian Health and Education Service Survey, which was conducted by Gadjah Mada University and the World Bank as a baseline survey for the evaluation of the PNPM-Generasi program (see Olken, Onishi and Wong 2008). The survey was conducted in June – August 2007, and took place in rural areas of 5 provinces in Indonesia. 12,000 households were interviewed, spread over approximately 2,400 villages. Because the survey followed the placement of the PNPM-Generasi program (and associated control areas), the 20% richest districts in each province are not included.

We designed short modules on informal taxation administered to households and to village heads. The module began by asking "Has there been community activities in repair/ cleaning/ maintenance/ construction of village/neighborhood infrastructure and facilities during the last 12 months?" If yes, the household was asked if they participated in the activities, and if so, what type of activity (road/bridge, schools, water/sanitation systems, irrigation systems, or religious/cemetery projects). Households were then asked how many total person-hours the household contributed as well as total cash and materials payments over the previous 12 months. Finally, both households and village heads were asked a series of questions about who decides how much each household should contribution and the sanctions for non-contribution; these questions are described in detail in the text.

Communities are defined as villages, which are subgroups of provinces, districts, and subdistricts.

### **A.1.5 Nigeria**

We examine the 2004 Nigerian Living Standards Survey. This nationally representative survey is a continuation of the series of National Integrated Surveys of Households conducted since 1981

by Federal Office of Statistics of Nigeria. The survey collected data on 19,158 households from September 2003 to August 2004.

We use questions four and five of section eight, Social Capital and Community Participation. These questions asked “Do you or any member of your household participate in community program(s)?” and, if yes, “Which of the following programs do you or a member of your household participate in?” We include in our estimation participation in the following categories: “construction of community school,” “maintenance of community roads and bridges,” and participation “in community development project.” While the survey does not specify a recall period for these questions, the instructions to the interviewer specify a recall period of 1 year for the previous question regarding “Coping Mechanisms in times of need.” We therefore take the recall period as 1 year.

Communities are defined as the urban or rural subsections of unique rics, which are subgroups of states.

### **A.1.6 Nicaragua**

We use data from the second Nicaraguan LSMS, “Encuesta Nacional de Hogares sobre Medición de Niveles de Vida.” They survey was conducted in 1998 by the National Institute for Statistics and the Census of Nicaragua with technical assistance from the World Bank. It covers 4,209 households in both urban and rural areas of all 15 departments and two autonomous regions, and is nationally representative

Question 57 of the household survey asks about household payments to construction and/or improvement of public facilities, such as schools, health centers, etc. The question also asks the respondent to indicate what “the contribution of this household was/were,” allowing us to separate labor and monetary payments. Note, however, that question 57 is conditional on a question 55, which asks households whether they were beneficiaries of any construction or improvement projects. Thus, our estimation is a lower-bound for the real proportion of household payments, since households who do not receive benefits might also contribute.

Communities are defined as *segmentos*, which are subgroups of *departamentos*, *municipios*, and *areas de supervision*.

### **A.1.7 Panama**

The 2003 Panama Living Standards Survey, *Encuesta de Niveles de Vida*, provides data from 6,363 households in rural and urban areas, and is nationally representative. It was designed and conducted by the Panamanian Ministry of Economy and Finance with the assistance of the World Bank.

Questions 2.A.1.a and 2.A.1.e ask households whether they have participated in works to benefit their or other communities (roads, schools, etc.) and whether they have donated money or goods for community works over the past 12 months.

Communities are defined as *corregimientos*, which are subgroups of regions, provinces, and districts.

### **A.1.8 Philippines**

We use the baseline survey of the KALAH-CIDSS project for the Philippines (see Chase and Holmemo 2005). It was conducted by the World Bank by the Asia-Pacific Policy Center as a

baseline for the evaluation of the KALAH! program, and covers 2,401 households. Due to the goals of the project, these households were selected only from rural areas of the 42 poorest provinces in the country, although each of the three geographical areas of the Philippines are represented.

Question 1a, part E of the household survey asks whether households participate in community projects: “Over the past six months, did you or any member of your family participate in any bayanihan in the barangay?” If yes, question 1ai asks for the three main activities and 1aiii provides a measure of the total time contributed to these three (per hours) for the period of the six months preceding the administration of the survey. We used a ratio of 6 hours per working day to convert the data to a daily measure. For our measure of participation, we included activities related to public cleaning, beautification, repair, construction, and other infrastructure work.

Communities are defined as barangays, which are subgroups of provinces and municipalities.

### **A.1.9 Vietnam**

The 2002 Vietnam LSMS survey is nationally representative and covers 29,532 households in both rural and urban areas. The survey was conducted by the General Statistical Office of Vietnam with technical assistance from the World Bank.

Question 3.18 of the household survey asks: “Have you contributed any public working days?” If yes, labor quantity information is provided in question 3.19: “In the past 12 months how many public working days without pay did you contribute?”

Information on monetary donations is found in question 6.b.3.1.402, which asks whether contributions were made in the last 12 months to public labor, and question 6.b.3.2.402 which asks the monetary value given in the last 12 months.

Communities are defined as communes/towns, which are subgroups of provinces/cities and districts.

### **A.1.10 Zambia**

The 1998 Zambia Living Conditions Monitoring Survey is nationally representative and covers 16,710 rural and urban households. The survey was conducted by the Central Statistical Office of Zambia.

Question 13.3 asks whether certain community projects (building/rehabilitations of school, health facility, roads, etc.) took place in the previous five years. If yes, question 13.18 of the household survey asks: “Did any member of your household participate in provision of materials, labour, management, or funds to the project?” Respondents can specify which of these categories they contributed, if any.

Communities are defined as centralities, which are subgroups of provinces, districts, census supervisory areas, standard enumeration areas, and stratum.

## **A.2 Construction of formal taxation variables**

We construct formal taxation payments for all countries for which we have data on the quantity of informal tax payments: Albania, Ethiopia, Indonesia, and the Philippines. We consider both direct tax payments by households, as well as indirect payments in the form of consumption taxes.

### A.2.1 Direct taxes

To capture direct tax payments, we use all available questions in household surveys that measure taxation directly, either as part of household expenditure or as part of non-farm business expenditures. Appendix Table 1 (below) shows all these variables and their questions and recall periods. We use the listed recall periods to normalize taxes to an annual basis.

### A.2.2 Indirect taxes

The tax structure of each country was investigated to determine the sources of indirect taxation for households. To maintain comparable construction of the variable across countries, we estimate indirect taxes as total value-added tax (VAT) combined with excise taxes paid on fuel, tobacco, and alcohol. Note that this measure does not include tariffs on imports and exports, which are a non-trivial component of indirect formal taxation in developing countries.

We construct the VAT base to include household expenditures unrelated to health, food, or education, as these categories are usually VAT exempt. Even to the extent that food is subject to VAT, since food purchases are predominantly in the informal sector, they are likely to be de facto exempt from VAT in our sample countries. Tobacco, alcohol, and fuel expenditures are considered separately due to their special rates of taxation.

The Ethiopian and Vietnamese surveys record the value of purchased alcohol separately from the value of alcohol self-produced or received as a gift. In these cases, we include only the value of purchased alcohol for tax consideration.

For each expenditure category, we calculate tax paid as follows:

$$Taxes = \frac{Tax\ Rate}{1 + Tax\ Rate} * Expenditure$$

The following sections report the details of the tax rates used in VAT calculations. The sources are shown in Appendix Table 2, and the recall periods for the corresponding questions are shown in Appendix Table 3.

Albania: The VAT and the tobacco excise tax were defined at 20% and 60%, respectively (see Table 2 below for relevant sources). Excise tax was defined at 50% for beer and varied from 16-100% for other types of alcohol. The excise tax on fuel ranged from 50-90% for the most important sources. Using this information, we chose the categorical tax rates for VAT (20%), tobacco (60%), alcohol (50%), and fuel (80%).

Ethiopia: The tobacco and alcohol excise taxes were set officially at 50% and 75%, respectively. A sales tax, rather than a VAT, was defined ranging from 5-15% by type of good or service. The majority of the goods included in our VAT base fell into the upper sales tax category and the only fuel source found to be tax exempt was kerosene. As such, we defined the categorical tax rates for VAT (15%), tobacco (75%), alcohol (50%), and fuel (15%).

Indonesia: The VAT was set at 10% and no fuel tax was charged. Tobacco was subject to an 8.4% VAT, an ad valorem tax ranging from 4-40% by type and production scale, and a specific tax ranging from 0-2%. The World Bank estimated the tobacco tax share as 30% of total retail price in 1999. Alcohol was charged VAT, excise tax, and luxury sales tax. The luxury sales tax was 40% for types of alcohol below 52 proof and 75% for those above. The excise tax on alcohol varied based on proof as well. Taking this information into account, we defined the categorical tax rates

for VAT (10%), tobacco (30%), alcohol (75%), and fuel (0%).

Philippines: The VAT was defined at 10% and was included in addition to excise tax for alcohol, tobacco, and fuel. While the tobacco excise tax varied by product type, the World Bank estimated the tobacco tax share as 63% of average retail price in 1999. The excise taxes on fuel and alcohol varied, respectively, by product type and by product type, price, and proof. Taking these facts into consideration, we chose the categorical tax rates for VAT (10%), tobacco (63%), alcohol (50%), and fuel (25%).

Vietnam: The fuel excise tax was defined at 10% and there were three categories of VAT at 5, 10, and 15%, with the majority of VAT base goods falling into the middle category. The tobacco excise tax varied based on product type and was set at 25, 45, or 65%. The World Bank estimated the tobacco tax share as 36% of average retail price in 1999. The alcohol excise tax varied by product type and proof. With this information, we defined the categorical tax rates for VAT (10%), tobacco (36%), alcohol (35%), and fuel (10%).

**Table A1: Questions used in total direct tax estimation**

	Year		Recall Period
Albania	2005	"Taxes and insurance" reported in non-farm business	1 month
		"Other Taxes (vehicle, radio and TV, etc)" reported in expenditure	12 Months
Ethiopia	1997	"Taxes and Levies" reported in expenditure	4 Months
Indonesia	2007	"Land and house tax; Vehicle tax; Income tax; Other taxes" reported in expenditure	12 months
Philippines	2003	"Taxes (income tax, real estate tax, car registration, etc.)" reported in expenditure	6 Months
Vietnam	2002	"All kinds of taxes (excluding production tax)" reported in expenditure	12 Months

**Table A2: Sources for VAT and excise tax rates**

Albania	Law No. 7928/1995; Law No. 8437/1998
Ethiopia	Proclamation No.68/1993; Proclamation No. 77/1997
Indonesia	Law No. 17/2000; Jakarta Post/July 19.2004; Tobacco Economics in Indonesia/2008; The Tobacco Source Book, Ministry of Health Republic of Indonesia/2004;
Philippines	Republic Act No. 8424/1997; World Bank Vietnam Tobacco Country Brief/1999
Vietnam	Law No. 2/1997/QH9; World Bank Vietnam Tobacco Country Brief/1999

**Table A3: Recall periods for indirect tax questions**

	VAT base	Tobacco	Alcohol	Fuel
Albania	30 days	30 days	30 days	30 days
Ethiopia	4 months	4 months	1 week	1 month
Indonesia	12 months	1 week	1 week	12 months
Philippines	6 months	3 days	3 days	1 month
Vietnam	12 months	12 months	12 months	12 months

### A.3 Dropping of Outliers

We drop observations for which any of the following three are true: (a) the reported total household days of labor contributed in the last year exceeds 50% of total possible yearly household working days (defined as 250 multiplied by the number of workers in the household); (b) the total monetized value of reported household days of labor contributed in the last year exceeds 50% of total yearly household expenditure; (c) the total reported value of yearly direct taxes exceeds total yearly household expenditure.

These restrictions affect only the data from Indonesia (0.22% dropped), Ethiopia (1.98% dropped), and Vietnam (0.01% dropped).

### A.4 References

Chase, Robert S and Camilla Holmemo, “Community Driven Development and Social Capital: Designing a Baseline Survey in the Philippines,” World Bank Report #32405-PH, 2005.

Olken, Benjamin A., Junko Onishi, and Susan Wong, “Conditional Community Transfers Baseline Survey”, mimeo, MIT, 2008.

## B Appendix B: Proofs

**Proof of Remark 1.** Suppose that, at the optimum payment level,  $\lambda_H > 0$ .

(i) Suppose  $SC_L$  does not bind.

Let the payment of the high type change to the new levels  $\lambda_H^* = \lambda_H - \epsilon$  and  $\tau_H^* = \tau_H + w_L\epsilon$ , for some small  $\epsilon > 0$ . At these new payment levels, the shirking constraint for both types would still hold.

For  $HI_H$ :

$$u(w_H(1 - \lambda_L) - \tau_L) - D \leq u(w_H(1 - \lambda_H) - \tau_H) \leq u(w_H(1 - \lambda_H) - \tau_H + (w_H - w_L)\epsilon) = u(w_H(1 - \lambda_H^*) - \tau_H^*) \implies HI_H \text{ still holds for } \lambda_H^* \text{ and } \tau_H^*.$$

For  $EC_H$ :  $u(w_H) - P \leq u(w_H(1 - \lambda_H) - \tau_H) \leq u(w_H(1 - \lambda_H^*) - \tau_H^*) \implies EC_H$  still holds for  $\lambda_H^*$  and  $\tau_H^*$ .

$HI_L$ ,  $EC_L$ , the government budget constraint and the low type's utility are unaffected by the changes in the high type's payments.

The high type's utility now becomes:

$u(w_H(1 - \lambda_H^*) - \tau_H^*) = u(w_H(1 - \lambda_H) - \tau_H + \epsilon(w_H - w_L)) > u(w_H(1 - \lambda_H) - \tau_H)$ . Thus, the high type can be made strictly better off without violating any of the constraints.

(ii) Suppose  $SC_L$  binds.

This implies  $\lambda_L > 0$ . Let the payments of the two types change such that, for some small  $\epsilon > 0$ ,  $\lambda_L^* = \lambda_L - \epsilon$ ,  $\lambda_H^* = \lambda_H - \epsilon$ ,  $\tau_L^* = \tau_L + w_L\epsilon$  and  $\tau_H^* = \tau_H + w_L\epsilon$ .

Decreasing  $\lambda_L$  and  $\lambda_H$  by  $\epsilon$  and increasing  $\tau_L$  by  $\epsilon$  would not change the low type's income or the  $SC_L$  constraint. So  $SC_L$  will still hold.

We next check that  $SC_H$  is still satisfied at the new payment levels.

At the previous allocation,  $S \geq u(w_H(1 - \lambda_L) - \tau_H) - u(w_H(1 - \lambda_H) - \tau_H)$ . At the new allocation, income in both utility terms is increased by  $\epsilon(w_H - w_L) > 0$ . Since the utility function is concave, this change will decrease the right-hand side of the inequality, so  $SC_H$  will still be satisfied.

As above,  $HI_H$ ,  $EC_H$ ,  $HI_L$ , and  $EC_L$  will continue to hold at the new payment levels. The government budget constraint and the low type's utility are unaffected by the changes in payments.

As before, the high type's utility now becomes:

$u(w_H(1 - \lambda_H^*) - \tau_H^*) = u(w_H(1 - \lambda_H) - \tau_H + \epsilon(w_H - w_L)) > u(w_H(1 - \lambda_H) - \tau_H)$ , so the high type can be made strictly better off without violating any of the constraints.

Thus, in both (i) and (ii),  $\forall \lambda_H > 0$ , social welfare can be increased without violating any of the constraints  $\implies$  at the optimum level of payments,  $\lambda_H = 0$ . ■

**Proof of Remark 2.** Notice that the non-negativity constraint and the fact that  $\lambda_H = 0$  at the optimum (Remark 1) imply  $\underline{\lambda} = 0$  and  $SC_H$  is slack.

Assume that there exists an allocation  $\lambda_L \geq 0$ ,  $\tau_L > 0$ ,  $\tau_H \geq 0$  such that the constraints are satisfied and the public good is provided. Thus,  $S \geq u(w_L - \tau_L) - u(w_L(1 - \lambda_L) - \tau_L)$ .

Let  $S^* = S + \Delta S$ ,  $\Delta S > 0$ . Thus,  $S^* > u(w_L - \tau_L) - u(w_L(1 - \lambda_L) - \tau_L)$  and  $SC_L$  is slack.

For some small  $\epsilon > 0$ , let  $\tau_L^* = \tau_L - w_L\epsilon$  and  $\lambda_L^* = \lambda_L + \epsilon$ . At these new payment levels  $SC_H$  and  $SC_L$  would still be satisfied.

Since  $u(w_L(1 - \lambda_L^*) - \tau_L^*) = u(w_L(1 - \lambda_L) - \tau_L)$ ,  $HI_L$  and  $EC_L$  are unchanged.  $EC_H$  is also unchanged.

However,



$u(w_H(1 - \lambda_L^*) - \tau_L^*) - D = u(w_H(1 - \lambda_L) - \tau_L - \epsilon(w_H - w_L)) - D < u(w_H(1 - \lambda_L) - \tau_L) \leq u(w_H(1 - \lambda_H) - \tau_H) \implies HI_H$  is slack  $\forall D \geq 0$ . Thus,  $HI_H$  would be satisfied for higher values of  $\tau_H$ . This is because it would now cost the high type more in foregone income if he were to deviate to the low type's tax package.

Since  $u(w_H(1 - \lambda_H) - \tau_H) > u(w_L(1 - \lambda_L^*) - \tau_L^*)$  and the utility function is concave,  $u'(w_H(1 - \lambda_H) - \tau_H) < u'(w_L(1 - \lambda_L^*) - \tau_L^*)$ .

Therefore, if  $EC_H$  is not binding at  $\tau_H$ ,  $\exists \delta > 0$  such that increasing  $\tau_H$  by  $\delta/\alpha$  and decreasing  $\tau_L$  by  $\delta/(1 - \alpha)$  will still satisfy  $HI_H$  and improve social welfare. If  $EC_H$  binds at  $\tau_H$ , then the change in the low type's tax mix (and the resulting slackness of  $HI_H$ ) does not allow for a change in  $\tau_H$ . Therefore, the total tax payments and the utilities of the two types will be unaffected.

Hence, as  $S^*$  increases, it is weakly optimal to decrease  $\tau_L$ . Therefore,  $\exists S_0 > 0$  such that  $\forall S \geq S_0$  setting  $\tau_L = 0$  can weakly increase social welfare. In this case, it is weakly better for the low type to pay only in labor and not in money, if his optimal total tax payment is positive. ■

**Proof of Remark 3.** First assume the social planner maximizes social welfare when  $\tau_H + w_H\lambda_H < \tau_L + w_L\lambda_L$ . Now consider the allocation  $\tau_H = \tau_L = \frac{G}{N}$ . If the constraints for the low type were satisfied at the previous allocation, they will still be satisfied at the new allocation.  $HI_H$  and  $SC_H$  will be satisfied for  $D = 0$  and  $S = 0$ , and  $EC_H$  will be satisfied as long as  $P \geq u(w_H) - u(w_H - \frac{G}{N})$ . Since  $w_H > w_L$  and the utility function is concave, the new allocation will result in a social welfare improvement.

Now assume the social planner maximizes social welfare when  $\tau_H + w_H\lambda_H = \tau_L + w_L\lambda_L$ .

(i) Suppose  $S = 0$ .

From Remark 1, we know that  $\lambda_H = 0$  and therefore  $\underline{\lambda} = 0$ .  $S = 0$  and the government budget constraint then imply that  $\lambda_L = 0$  and  $\tau_H = \tau_L = \frac{G}{N}$ . At this allocation,  $HI_H$  will be satisfied at  $D = 0$  and is therefore slack  $\forall D > 0$ . If the condition given in the remark holds (i.e.,  $P > u(w_H) - u(w_H - \frac{G}{N})$ ), then  $EC_H$  will also be slack.

Then  $\exists \epsilon > 0$  such that  $HI_H$  and  $EC_H$  are still satisfied for  $\tau_H^* = \tau_H + \epsilon/\alpha$  and  $\tau_L^* = \tau_L - \epsilon/(1 - \alpha)$ . This change in  $\tau_H$  and  $\tau_L$  leaves the government budget constraint unchanged. If the constraints for the low type were satisfied at  $(\tau_H, \tau_L)$ , they will still be satisfied at  $(\tau_H^*, \tau_L^*)$ .

Since the utility function is concave,  $u'(w_H - \frac{G}{N}) < u'(w_L - \frac{G}{N})$ . Therefore, increasing  $\tau_H$  by  $\epsilon/\alpha$  and decreasing  $\tau_L$  by  $\epsilon/(1 - \alpha)$  will improve social welfare.

(ii) Suppose  $D = 0$ .

From Remark 1, we know that  $\lambda_H = 0$  and therefore  $\underline{\lambda} = 0$ , so  $SC_H$  is slack. If  $D = 0$ ,  $HI_H$  can be rewritten as

$$u(w_H - \tau_H) \geq u(w_H(1 - \lambda_L) - \tau_L)$$

$HI_H$  will be slack for the allocation given  $(\tau_H = \tau_L + w_L\lambda_L)$  as long as  $\lambda_L > 0$ . As above, if  $P > u(w_H) - u(w_H - \frac{G}{N})$ , then  $EC_H$  will also be slack.

If the allocation given has  $\lambda_L > 0$ , then we can achieve a social welfare improvement by increasing  $\tau_H$  and reducing  $\tau_L$  as in case (i) above.

Now suppose the allocation given has  $\lambda_L = 0$ .  $SC_L$  will then be binding at  $S = 0$  and slack for  $\forall S > 0$ . Then,  $\exists \eta > 0$  such that we can set  $\lambda_L^* = \eta$  and  $\tau_L^* = \tau_L - w_L\eta$  and  $SC_L$  will still be satisfied. This change does not affect the total tax payment of the low type, the government budget constraint or  $HI_L$ . We can then achieve a social welfare improvement by increasing  $\tau_H$  and reducing  $\tau_L$  as in case (i) above. ■

**Proof of Remark 4.** We denote the low type's income and tax payments by the subscript  $M$ , to differentiate them from the notation for the unskilled wage rate at which government values labor,  $w_L$ . The fact that at the optimum level of payments  $\lambda_H = 0$  can be shown using a proof similar to the one used for Remark 1 with the additional condition that if  $SC_M$  does not bind, then it must be the case that  $D > u(w_M(1 - \lambda_H) - \tau_H) - u(w_M(1 - \lambda_M) - \tau_M)$  in order for  $HI_M$  to be satisfied.

To show that the tax payments are strictly increasing in income, the proof is similar to the one used to prove Remark 3. ■

**Example 1** Let  $U(y_i, g) = \ln(y_i) + \theta g$ , where  $y_i = w_i(1 - \lambda_i) - \tau_i$ . We take  $w_H = 9$ ,  $w_M = 4$ ,  $w_L = 3.5$ ,  $\alpha = 1/3$ ,  $P = 1$ ,  $D = \ln(10/7)$ ,  $S = \ln(3/2)$ ,  $G/N = 2$  and  $\theta = 2$ .

In the first best, when no constraints bind, the optimal solution would involve  $\tau_H = 16/3$  and  $\tau_M = 1/3$ . The social planner would not use any labor taxes since both individuals' labor is publicly valued at a lower rate than their outside wage.

If we introduce the enforcement, hidden income and shirking constraints, then the hidden income constraint for the high type would not be satisfied at the first-best values of  $\tau_H$  and  $\tau_M$ . Thus, labor would have to be used as a screening device to make the low type's tax mix less attractive to the high type. By requiring the low type to pay some taxes in labor, the high type's utility cost of switching to the low type's tax mix is increased since the high type values his labor at a higher wage rate than the government. However, the introduction of labor payments also increases the low type's total tax payment, since his labor is also valued at a lower rate than his outside wage. Thus,  $P$ ,  $D$  and  $S$  must be high enough so that the constraints hold even after these changes in the tax mix.

In this example, after switching the low type's payment to labor instead of money, the hidden income constraint for the high type will be satisfied with equality. Solving the constrained maximization numerically, at the optimal level,  $\tau_H^* = 4.26$ ,  $\lambda_H^* = 0$  and  $\tau_M^* = 0$ ,  $\lambda_M^* \simeq 0.25$ . The total tax payment for the low type increases to  $w_M \lambda_M \simeq 1$ , reflecting the need to use the low type's payment as a screening device. One can check, for example, that welfare under this scenario is greater than, for example, setting  $\tau_H = \tau_L$ , or setting  $\lambda_L = 0$  and setting  $\tau_H$  and  $\tau_L$  such  $HI_H$  binds.

Note that we can always guarantee that it will continue to be optimal to provide the public good by setting  $\theta$  high enough.

**Example 2** As in the previous example, let  $U(y_i, g) = \ln(y_i) + \theta g$ , where  $y_i = w_i(1 - \lambda_i) - \tau_i$ . Assume there are three types of individuals in the community: high-skilled, medium-skilled and low-skilled, each representing a share  $\alpha = 1/3$  of the population. We take  $w_H = 11$ ,  $w_M = 5$ ,  $w_L = 4.5$ ,  $G/N = 2$  and  $\theta = 2$ . Let  $D_{ij}$  denote the utility cost for individual of type  $i$  to hide income and pretend to be of type  $j$ . Assume the punishment and utility cost of shirking  $P$  and  $S$  are identical for all types. We let  $P = 1$ ,  $S = \ln(3/2)$ ,  $D_{HM} = D_{MH} = \ln(1.45)$ ,  $D_{HL} = D_{LH} = \ln(1.9)$ ,  $D_{ML} = D_{LM} = \ln(1.3)$ . Notice that the cost of hiding income is increasing with the amount hidden in such a way that switching to the medium type's tax rates is always more attractive for the high type than switching to the low type's tax rates.

In the first best case, when no constraints bind, the optimal allocation involves  $\tau_H = 6$ ,  $\tau_M = 0$ ,  $\tau_L = 0$  and no labor payments. This allocation reflects the large difference in income between the high type and the other two types. However, at this allocation, the hidden income constraint would not hold for the high type, who would have an incentive to switch to be the medium type's schedule. Therefore, the constrained maximization problem will use labor payments as a method of making the medium type's payment less attractive to the high type. (In this example, the large gap between the

high and medium wages makes increasing the medium type's labor payments preferable to increasing his monetary payments.)

Solving the constrained maximization problem numerically yields  $\tau_H = 5$ ,  $\tau_M = 0$ ,  $\lambda_M = 0.214$ ,  $\tau_L = 0$  and  $\lambda_L = 0$ . In this example, we obtain a case in which the lowest type is not required to pay anything, the medium-skilled type is required to supply labor, and the high-skilled type only pays in money.

Note that we can always guarantee that it will continue to be optimal to provide the public good by setting  $\theta$  high enough.