



Efficiency and equity tradeoffs: incentive-compatible contracts revisited

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Abstract

While the efficiency of certain contractual choices has been well established, less attention has been given to the distributional outcomes of contracting in natural resource-based industries. Data from a case study of seed gatherers in Honduras demonstrates that workers paid under a relative payment system receive an earnings premium of about 25%, of which 40% cannot be explained by observed differences in worker productivity. A theoretical agency model is outlined in the appendix to explain why workers under tournaments necessarily enjoy a higher return than those under piece-rates, implying a more skewed income distribution as suggested in the efficiency wage literature. © 2002 Elsevier Science B.V. All rights reserved.

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1. Introduction

Contractual arrangements in less-developed countries often compensate for extreme informational problems and imperfections in other markets. The relative efficiency of different incentive-compatible contracts, rather than their distributional implications, usually has been the focus of inquiry. But path-dependent processes in contracting are

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important (Bardhan, 1989). Labor institutions affect earnings differentials, and the distribution of income then affects future contract optimum.¹

Most principal-agent models to date have the assumption that agents are just paid their opportunity wage, implying these labor contracts should have a neutral distributional impact. Some lines of research part from this assumption. Varying the range of legal liability an agent faces affects whether a reservation utility constraint is binding (Sappington, 1983). In a market characterized by monopsonistic competition, a landlord can demand servility by limiting the horizon of agents so their payments may fall below an opportunity wage (Basu, 1983; Schaffner, 1995). But agents with bargaining power over a principal can receive compensation above the reservation utility (Bell, 1989). Or workers may receive “efficiency rents” as a contractual incentive for self-supervision. Efficiency wage contracts (such as permanent labor arrangements) require wage premiums and firing penalties to extract effort (Anderson-Schaffner, 1993; Bardhan, 1979; Eswaran and Kotwal, 1985; Ray, 1998; Shapiro and Stiglitz, 1984). With this endogenous contract enforcement involuntary unemployment and persistent earnings differentials exist in equilibrium.

This paper uses data from the Honduran farm-raised shrimp export industry to explore the distributional implications of two types of contracts made to solve moral hazard problems: relative payments and piece-rates. I find that workers paid under relative payments receive an earnings premium of about 25%, of which 40% cannot be explained by observed differences in worker productivity. I provide a theoretical explanation for this result. Under some conditions, relative payment schemes resemble efficiency wage schemes in that they pay workers rents above their reservation wages. In contrast, piece rate contracts provide earnings equal to a worker’s reservation wage. The paper provides a skeleton outline of a model developed originally by Malcomson (1984). I emphasize the firing penalty case of his model and apply the existing theory to the new setting of natural resource gathering.

The paper is organized as follows. Section 2 discusses earlier applications of agency theory to labor contracts in natural resource industries. Section 3 presents the framework of the empirical analysis. Section 4 presents empirical results. The concluding section discusses the social outcomes of contractual design. Appendix A presents the theoretical model.

2. Trends and models of contractual choice and equity

2.1. Contractual trends in natural resource industries

Moral hazard problems are common in extraction activities, such as fishing at sea and rubber tree tapping (Platteau and Nugent, 1992; Gersovitz, 1992; Barham and Coomes,

¹ For a related model of endogenous firm formation and contract organization dependent on the distribution of wealth and inequality, see Legros and Newman (1996).

1994).² Typically, a product contractor hires gatherers to harvest natural goods. Gatherers work without supervision for long periods across large distances. The contractor has incomplete information since the effects of effort cannot be separated from the impact of the natural environment. Both can gain from an agency relationship. Capital-scarce gatherers need special provisions and product market access. The contractor desires the highest return on the capital equipment, so the unsupervisable gatherers' bringing in a large quantity maximizes this objective. An interlinked contract usually emerges with the contractor providing equipment and a payment to labor in exchange for exclusive marketing of the gatherer's product under pre-specified terms. Such contracts may be short-term or may cover several seasons.

Wide opportunities for worker shirking and few risk management mechanisms explain why fixed wage or fixed rental arrangements in this type of petty extraction are rarely used. Piece-rate schemes are more common.³ Another common type of contract is a relative payment scheme in which agents are ranked according to their performance (Nalebuff and Stiglitz, 1983; Green and Stokey, 1983). Payment is made on the basis of relative output among a set of workers. The expected compensation package to the winner is greater than that given to the loser. Losers risk being cut off from future contracting, the equivalent to being fired. Most of the literature takes the winner's payments as comprised of a sure fixed wage, plus a share of the revenues.⁴

Pairwise optimal contract choice for each task is usually based on the relative costs and benefits of monitoring, supervision, and recruitment implied by each payment form. When several payment forms are observed for the same task, worker type and labor market conditions determine the distribution of workers across contracts. For example, in some agrarian settings, it is observed that both permanent and casual labor contracts are offered for the same (set of) tasks. Differing risk preferences may explain worker self-selection across contract types (Bardhan, 1983). However, this reasoning seems less compelling for gatherers as environmental parameters (the strength of idiosyncratic or covariate shocks) determine the relative risk-reducing effects of relative payments and piece rates (Nalebuff and Stiglitz, 1983). Ray (1998) suggests that permanent contracts

² Following Platteau and Nugent (1992), the focus here is on the possible effort shirking by agents, rather than the traditional hyper-effort assumed in the "common property" fisheries economics literature. This implies no negative externalities between gatherers in open access settings with overfishing. Territoriality of a gatherer's spot usually occurs. If gatherers were competing with each other in an open access setting so that high effort by one diminished the product captured by another gatherer, the signal between a gatherer's own effort and the product delivered would be weakened.

³ Piece-rates are a variation of share contracts in that the contractor offers about 33–50% of the final resale price to the gatherer, with the difference being the contractor's return on the boat and other provisions. Piece-rate workers receive incentives as (partial) residual claimants who bear some risk (yet less than that under a fixed rental contract). Commonly a side-payment parameter "*B*" is added to the piece-rate wage for ex-post distributional purposes and to assure that ex-ante the agent accepts the contract. The variable "*B*" would be positive wages in bad states or negative "rents" in extremely good states. Of course, sharecroppers often enjoy more autonomy since they bring more (unmarketable) inputs and specialized knowledge to activity. Yet in each case the returns to the agent are directly related to output.

⁴ Notable examples of relative payments/tournaments include renewal clauses in tenancy leases (Banerji and Rashid, 1996) and payment rates to poultry growers determined by the grower's ranking (Knoeber and Thurman, 1994).

are effective in settings of low casual wages since the gain from not shirking and being retained becomes more apparent. On the other hand, Eswaran and Kotwal (1985) expect more permanent contracts in tight labor markets, as employers substitute away from relatively more expensive casual contracts or try to avoid continuous recruitment costs. Hart (1986) shows that permanent contracts occur in both slack and tight labor markets, since these contracts secure worker loyalty and other (non-marketed) services, such as political support and asset protection.

2.2. A model of short-term contracts and earnings differentials

How labor market conditions affect the proportion of relative payments alongside other untied labor contracts has not yet been explored in the literature. And there has been little attempt to decompose earnings differentials and link them to contractual sorting processes. A principal-agent specification of relative payment and piece-rate arrangements explores these partial equilibrium questions. It contains simple payment terms of fixed wages or piece rates that reflect the reality of an actual gathering setting. The model extends the earlier work on efficiency wages (Shapiro and Stiglitz, 1984), work incentives (Malcomson, 1984), uncertainty and incentive-compatible contracts (Green and Stokey, 1983; Nalebuff and Stiglitz, 1983), and multi-period relative payments (Banerji and Rashid, 1996).

The framework for this model is one in which a labor contractor hires a gatherer to collect a product that will be sold to a third party; contracting further along the industrial chain is not examined. There are N identical landless workers who can be hired by a single principal. The principal owns an amount of capital that is divided across working agents. Each gatherer receives the same amount of equipment, so a representative agent approach is used. The labor market in which contracting occurs is characterized by high unemployment and an exogenously given reservation wage (w_0), which determines the reservation utility \bar{U} . So gatherers take or leave a contract designed to maximize the contractor's profit.

Assume contractors use two wage packages—relative payments and piece rates—to encourage self-supervision and provide incentives for effort. Although both compensation forms operate simultaneously, their timing is different. Relative payments embody multi-period incentives. The agent considers future income when making current decisions since the pay-off on first-period effort is received in the second period. Piece-rates incorporate single period incentives and rewards to effort. Thus comparison of the contracts' relative efficiency effects in effort extraction may be misguided. The analysis here, however, only seeks to characterize trends in earnings and income distribution stemming from the two contracts.

The construction of the model is in Appendix A.1. It suggests winning gatherers in a relative payments scheme may be receiving expected compensation above the reservation wage as an enforcement rent for "self-supervision". Dye (1984) notes the need for such gaps arising when tournaments operate simultaneously with other contractual arrangements. If the returns in the loser's "fall back" are too attractive, the worker dismisses the benefit of winning the relative payment, and effort levels fall. Previous work implies the expected utility from piece-rates is equal to the agent's reservation utility. And in locations

of multiple contract equilibria, relative payment gatherers may do better than those paid piece rates and the going wage ($w^R \geq w_o \approx w^P$). Thus a testable hypothesis is whether a more skewed income distribution pattern emerges in settings of relative payments schemes where multiple contract types are used.

3. Empirical framework

The empirical analysis has two goals. The first goal is to determine if gatherers paid under relative payment schemes indeed receive wages with higher means and higher variances. The second goal is to determine whether observed average earnings differentials across the two types of contracts are related to contractual rents per se. This requires controlling for gatherer productivity factors and the sorting process across contracts.

Some light on the first question is shed by the descriptive and Gini income distribution statistics. More detailed intra-year data can determine if earnings differentials persist across the slack and high seasons.

The Gini income distribution and the rank statistics (based on yearly data) also provide information about a gatherer's relative income position in the community. Consider the correlation coefficient between contract type and income rank that associates the dummy variable of contractual arrangement with that household's total and source income rank.⁵ A positive association is expected as the relative payment is assigned the dummy variable of one. Across two contractual regimes indexed by "C", these zero-order correlations may be expressed as:

$$\rho_{c,rs} = \text{the correlation between contractual regime and gathering income source ranking} \quad (1)$$

$$\rho_{c,r} = \text{the correlation between contractual regime and total income ranking}$$

Yet other determinants of the observed earnings differentials may be relevant. To isolate the role of contracts in determining earnings, the conventional (pooled) regression specification begins with a dummy variable for contractual impact, or sub-samples for complete interaction:

$$\ln Y_i = \alpha + bX_i + cC_i + \varepsilon_i \quad (2a)$$

$$\ln Y_R = \alpha + b_R X_i + \varepsilon_R \quad (2b)$$

$$\ln Y_P = \alpha + b_P X_i + \varepsilon_P \quad (2c)$$

Where $\ln Y_i$ = the natural logarithm of gathering daily earnings; C_i = the contractual regime for gathering; X_i = human capital and other explanatory variables; R, P = subscripts for relative payment and piece-rate contract regimes.

⁵ Such correlation coefficients parallel the logic of rank regression techniques (e.g. Olejnik and Algina, 1985).

The size of the coefficient on C measures the unconditional contract wage effect, not unlike the traditional union wage or discrimination effect. The interaction of contractual outcome with other variables is determined by using the sub-sample regressions to test whether $b_R = b_P$. This differential may also reflect the interaction of contractual outcomes with productivity, although both relative payment schemes and piece-rates have strong incentive effects.

Oaxaca decompositions of Eqs. (2b) and (2c) break up the contractual earnings differential into the component due to contractual wage structures and the component associated with observed productivity-enhancing variables (Oaxaca, 1973). Although traditionally applied to discrimination questions, the Oaxaca decomposition can isolate the part of earnings differentials that are unexplained by productivity-differences across workers. The unexplained component due to differences in wage structures may include an efficiency wage premium and residual variance.

Regression results on daily earnings across the contractual sub-samples of Eqs. (2a,b,c) form the decomposition equation. It can be evaluated at two sets of mean explanatory variables, with the b_s as coefficients across contractual sub-groups, or restated in three components with a competitive wage structure b^* as suggested by Cotton (1988)⁶:

$$\begin{aligned} \text{Ln}\bar{Y}_R - \text{Ln}\bar{Y}_P &= b_R(\bar{X}_R - \bar{X}_P) + \bar{X}_P(b_R - b_P) \\ &\times (\text{evaluated at the piece - rate means}) \end{aligned} \quad (3a)$$

$$\begin{aligned} \text{Ln}\bar{Y}_R - \text{Ln}\bar{Y}_P &= b_R(\bar{X}_R - \bar{X}_P) + \bar{X}_R(b_R - b_P) \\ &\times (\text{evaluated at relative payment means}) \end{aligned} \quad (3b)$$

$$\begin{aligned} \text{Ln}\bar{Y}_R - \text{Ln}\bar{Y}_P &= \bar{X}_R(b_R - b^*) + \bar{X}_P(b^* - b_P) + (\bar{X}_R - \bar{X}_P)b^* \\ &\times (\text{evaluated at both means with the weighted average} \\ &\text{wage structure}). \end{aligned} \quad (3c)$$

Of course, omitted variables and non-exogenous sorting across contracts must be considered. Controls for cross-equation covariance and self-selection bias are needed since there may be a disproportionate representation under the relative payments scheme of gatherers who, due to their unobserved skills, would have had higher wages anyway. If variables such as age, schooling, past experience, and asset levels are significant in the selection process and earnings generation, the gatherers' self-selection across contracts

⁶ The wage differential between subgroups is usually decomposed into a discrimination and a productivity component as: $w_n - w_i = (d_i - d_n) + (f_n - f_i)$ with subscripts n and i representing, say, native and immigrant worker subgroups (Bucci and Tenorio, 1997). Following Cotton (1988), this expression is divided into three parts as: $w_n - w_i = [w_n - f_n] + [f_i - w_i] + [f_n - f_i]$, with the first two terms as the overvaluation of payments to the top group and the disadvantage of the bottom group and the third as the wage gap due to productivity differentials. For Eq. (3c) this requires calculating a non-discriminatory (non-efficiency) wage structure b^* using a weighted average of each contract group's wage. Oaxaca and Ransom (1994) suggest the earnings differential attributed to wage structures is closer to this last measure, although the method assumes that one or the other (group) wage structure is the competitive structure. Bucci and Tenorio (1997) discuss the sensitivity of the decomposition results.

may not reflect efficiency wage rents. But sorting along the lines of non-productivity enhancing variables suggests some form of rationing by contractors, with wage differences more directly linked to efficiency rents. Thus selectivity-corrected earnings estimates, using an endogenous union sorting and wage model (Lee, 1978), are included to highlight the sorting process and adjust for possible correlation in the unobservable variables.

4. Testing contractual sorting and income distribution

4.1. The case study setting and data

The analysis uses a case study of shrimp larva gatherers in southern Honduras. Mariculture (farm-raised shrimp) firms are an important industry for the regional economy in terms of employment opportunities and foreign exchange generation (DeWalt et al., 1996). Since 1983, government agencies have granted renewable long-term land leases of over 31,000 hectares to shrimp-exporting companies at a low rental rate. Fences around community seasonal winter lagoons have stimulated controversy and poaching problems, as elsewhere in the developing world (Bailey, 1988). Following pond construction, shrimp farmers aim to produce a high-quality export by processing raw natural resources through the stages of larva (shrimp seed) collection, grow-out, harvest, processing and packing. Laws setting a high minimum wage in export agro-industries and requiring severance pay for permanent workers could be influencing the farm managers' heavy recruiting through contractors.

Some families residing near the farms are hired through contractors for shrimp larva gathering work. This gathering involves pushing a dense hoop net along the edge of an estuary during low tide; small fish larva are collected in the net and passed by hand into collection buckets and tanks. The gatherer's (hidden) effort and the total larva in the tide (itself a function of water temperature, salinity and the lunar cycle) both influence the amount of larva collected.

At least two distinct payment systems have existed for the gathering work. In the first, large firms aim to have a steady supply of larva for a fixed pond stocking date. Given their rather inelastic demand for larva, farm managers retain certain labor contractors on-call; these contractors then recruit and pay gatherers a fixed daily wage to collect larva. However, managers then rank the boats by catch levels and choose not to invite back certain contractors and gatherers for the next month. Only some of the gatherers are allowed to continue working while the natural larva is plentiful.⁷

In the second system, contractors serve as buffer suppliers for large farms or the primary supplier for small farms. These contractors sell larva on an irregular basis to the farms, and pay the gatherers on the spot a piece-rate for the larva delivered.

Data on work and earnings patterns of these two gathering groups were collected in 1993 using a two-stage stratified sampling technique in three villages (Village A, Village B, and Village C) impacted by shrimp farming. Villages were chosen to highlight the

⁷ In the period of data collection, I observed about one-third of the boats and their crews "fired" monthly.

different patterns in firm structure, property rights changes, and labor supply conditions. Then 145 households were randomly selected from within work strata groups proportional to occupational divisions in the village economy. To accurately track income across seasons, repeated interviews over 10 rounds were undertaken. There is a high season of larva activity between February–June, and a low season from July–November. The resulting (panel) data set includes information on demographics, earnings and work trends. Among those surveyed, young men from 105 households gathered larva for at least one month in the survey period.

In Village C, eight large farms have started growout ponds over some 3580 hectares. The dozen large operations of this conflictive zone provide some permanent and temporary employment and extra worker benefits through solidarity associations with savings clubs and company stores. In Village C, low season unemployment (of the full sample) was calculated to be 11.1% from labor market activity questions added to the final survey round.

In Village B, the piece-rate system is the norm for gathering, and 25 smaller family mariculture farms operate on 1187 hectares. Only 30% of the wetland area has been granted to concessionaires. Salt farms along the coastal fringe are the other employers in the zone. Unemployment in Village B was calculated at 7.1%.

Finally, in Village A multiple arrangements exist for gathering, and only 32% of the wetland area has been developed into shrimp ponds. The region has a tradition of self-employment enterprises in shellfish and firewood gathering, and unemployment was calculated at only 2.4%. The average daily wage and income per capita in village A were higher than those in the other locations.

4.2. An overview of income distribution in the gathering economy

The data in Table 1a allows us to observe the effect of contractual parameters across various points of the year in a manner similar to that of Mukherjee and Ray (1992). In

Table 1a
Larva income data from monthly data (105 gathering households across 10 months surveyed)

	Full sample (<i>n</i> = 669)	Relative payment (<i>n</i> = 298)	Piece-rate (<i>n</i> = 371)
Inputed larva income per day (lps. ^a) *	29.94	37.10	24.20
Days gathering/month *	12.90	14.54	11.59
Total HH monthly income per adult equivalent (lps.) *	152.40	184.04	127.00
High season daily income from gathering *	31.60	41.36	23.36
High season days gathering *	15.22	17.71	13.10
High season monthly income per adult equivalent *	159.92	215.48	112.98
High season employment (days/month/person)	11.60		
Low season daily income from gathering	26.49	27.40	25.83
Low season days gathering	8.09	7.33	8.63
Low season monthly income per adult equivalent *	136.75	112.52	154.25
Low season employment (days/month/person)	10.88		

^a 5.5 lps. = US\$1 in 1993.

* Indicates a significant difference in sub-group means at the 1% level using a *t*-test.

general, those paid under the relative payment system receive a higher daily wage and worked more days each month. The log mean difference is 0.38 in log daily wages (approximately 25%) across gatherers working under relative payments and piece rates. The relative payment gatherers' total household income from all sources of work was also higher, indicating that returns from other activities did not compensate for the lower earnings of those paid piece rates for gathering.

Seasonal differences appear. More days of gathering work occur in the high season months of February–June, and during this period relative payment workers earned significantly more than they did in the low season and significantly more than the piece-rate workers did. During the low season, the daily wage difference across contracts was insignificant. Although moving upward, piece-rate gathering daily wages are still below those of relative payments for an incomplete wage adjustment process. Both groups work significantly fewer days in gathering, suggesting some substitution into other activities and little tying of the contracts.

Table 1b
Year variable definitions and descriptive statistics

	Gatherer sample, <i>n</i> = 105	Relative payment, <i>n</i> = 52	Piece-rate, <i>n</i> = 53
Total income across year per adult equivalent (lps. ^a)	1516.14	1678.73	1356.61
Logged total gathering income across year *	7.78 (2383 lps.)	8.02 (3051 lps.)	7.45 (1728 lps.)
Imputed log daily wage *	3.24 (27.38 lps.)	3.42 (30.51 lps.)	3.07 (23.99 lps.)
Days worked gathering *	83.13	92.23	70.85
Adult equivalents	4.50	4.60	4.47
<i>Worker characteristics</i>			
Age: years age of the gatherer/ head	30.31	28.25	32.34
Education: years of formal schooling *	2.86	2.88	2.83
Experience: years larva gathering pre-1993	3.26	3.04	3.47
Literacy *: a dummy variable = 1 if gatherer/ head is literate	0.62	0.67	0.57
Landholdings: units of land used by HH	1.30	1.26	1.34
<i>Contractor variables</i>			
Kinship *: a dummy variable = 1 if labor contractor is a relative	0.27	0.46	0.08
Contractor markets *: number of outlets	2.21	1.19	3.21
<i>Geography</i>			
Village A: a dummy variable = 1 for residence	0.33	0.37	0.30
Village B *: a dummy variable = 1 for residence	0.35	0.02	0.68
Village C *: a dummy variable = 1 for residence	0.31	0.62	0.02

^a 5.5 lps. = US\$1 in 1993.

^b Indicates a weighted mean of residence and contract affiliation.

* Indicates a significant difference in group means at the 95% level.

Table 1b provides a yearly compression of the data with a complete list and summary statistics of the time-invariant human capital variables used to estimate the association statistics. During the year, 53 of the gatherers were paid under piece-rate arrangements and 52 received a fixed salary under the relative payment incentive scheme. When gatherers worked in the low season, they tended to return to their previous contractor under the original payment arrangements. There was little mobility across contractual forms, with only 10 of the relative payment gatherers opting into a piece-rate scheme for three months during the low season.

Again a significant earnings differential of about 25% appears across the contracts. This is because daily pay rates are higher under relative payments. Households working in shrimp sector/relative payment earned at least a fixed base of 17.5–21 lempiras (lps.) (US\$2.5–3), which is more than those continuing in traditional labor. Going wages paid to workers on cattle ranches or corn plots were 10–15 lps. (US\$1.43–2.14) per day. The imputed daily wages thus show both relative payment and piece-rate workers earning more than the going wage ($w^R > w^P \geq w_o$), although this difference is greater for those under relative payments. The difference is most acute in Village A, where relative payment gatherers earned 4769.50 lps. across the year and gatherers paid under piece-rate earned 1755.80 lps. (and imputed daily gathering wages were 36.63 and 29.64 lps. respectively). Table 1b also suggests that gatherers in the relative payment group are younger, better-educated, literate relatives (kin) of a labor contractor.

Tables 1a and b pool data from all three villages, so trends in intra-village income distribution are obscured. Tables 2 and 3 present the common measures of income distribution; Table 2 reports the larva gathering income of those households identifying themselves as gatherers, while Table 3 includes the total household income from the whole sample. The Gini coefficient and variation statistics of Table 2 show that income distribution among the gatherers within a village is not highly skewed, but in Table 3 polarities emerge between gatherers and other residents of the village (earning the opportunity wage). In Table 2 there is moderate dispersion of gathering income and the shares accruing to the poorest and wealthiest gatherers. If anything, the income pattern among gatherers in Village C is more closely concentrated around the mean due to the fixed wage payments embodied in the relative payment contractual arrangements. The results were similar when gathering income per adult equivalent was used as an alternative welfare measure.

Table 2
Gathering income distribution across gatherers

Village	Contractual regime	Gini coefficient ^a	Coefficient of variation	Income share bottom 20%	Income share top 20%	Correlation rank and contract ^a
Village A	Mixed	0.34	0.61	4.19%	37.07%	0.75
Village B	Piece-rate	0.34	0.71	8.03%	43.34%	-0.07
Village C	Relative payment	0.32	0.58	4.06%	33.80%	0.36
Pooled		0.39	0.72	4.97%	43.59%	0.45

^a The coefficients and correlation were somewhat smaller, yet in the same ordinal rank, when using larva income per day as the dependent variable.

Table 3
Total income distribution across all households

Village	Contractual regime	Gini coefficient ^a	Coefficient of variation	Income share bottom 20%	Income share top 20%	Correlation rank and contract ^a
Village A	Mixed	0.23	0.43	8.86%	31.72%	0.48
Village B	Piece-rate	0.23	0.42	9.10%	31.21%	0.09
Village C	Relative payment	0.38	0.73	4.11%	43.14%	0.33
Pooled		0.32	0.70	5.35%	43.17%	0.37

^a The coefficients and correlation were somewhat smaller, yet in the same ordinal rank, when using total income per day as the dependent variable.

Table 3 provides some support to the idea that relative payment gatherers should earn above the reservation wage. In Village C there is high unemployment and the predominance of relative payment gathering, and village income distribution is highly skewed. Better-off households earn nearly 10 times that of poorer households. However, in Village B, the gatherers working primarily under piece rates earn in line with other households at the going wage. Over 50% of the population participates in gathering, so it is not surprising that gathering earnings are close to those from other lines of work. A narrower dispersion of income is observed. In Village A, where both gathering contractual arrangements exist side-by-side, the smaller Gini coefficient suggests the variety of contracts in place tends to even out earnings differentials.

Tables 2 and 3 further break down the village position-contract issue by incorporating the correlation coefficients of Eq. (1). The correlation coefficient between contract and larva income rank is strong and positive in Village A where there is the most contractual variation. So relative payment gatherers are the highest-paid gatherers and the better-off members of the local labor market. This supports the propositions developed in Appendix A. But the few relative payment gatherers do not perform well in Village B where piece-rates are the norm. And in Village C the impact of mariculture on the labor market has been articulated both through gathering, changes in public land access, and a range of jobs, so that other employment is a large source of village income variation.

4.3. Contract assignment and earnings differentials

The second concern of the empirical analysis is to assess whether the observed earnings differentials are related to the employment institutional arrangements per se. The OLS estimates of Eqs. (2a,b,c) provide a naive estimate of the contractual wage gap of around 20%.⁸ The results in Table 4 incorporate White's correction for heteroskedasticity as the Breusch–Pagan Chi-squared statistic was significant.⁹ The human capital variables of literacy and years of gathering experience both increase daily wages, particularly for those paid piece rate. The insignificant coefficient on the days worked variable suggests wage

⁸ The explanatory variable coefficients normally are interpreted as the percentage impact on Y per unit change in x , but correct expression for the dummy variable percentage impact is $e^{\beta} - 1$.

⁹ The test statistic was 16.68, which is significant at the 99% level for 7 df .

Table 4

OLS wage differentials by contract (dependent variable is log daily larva income in 1993 lempiras)

	Pooled	Relative payment	Piece-rate
Constant	3.09*, ** (23.04)	3.75 (21.06)	2.83 (20.47)
Literacy	0.13 (2.29)	0.06 (0.98)	0.10 (1.03)
Larva experience	0.05 (3.27)	-0.02 (-1.07)	0.09 (4.49)
Gatherer age	-0.002 (-0.84)	-0.007 (-2.64)	0.002 (0.50)
Days gathering	0.0009 (1.24)	0.0007 (0.76)	0.001 (0.89)
Village B	-0.35 (-3.65)	-0.28 (-2.93)	-0.35 (-3.48)
Village C	-0.15 (-2.14)	-0.30 (-4.48)	-0.02 (-0.13)
Relative payment	0.18 (1.92)		
Sample size	105	52	53
F-statistic	12.13	6.86	4.87
Adjusted R ²	0.43	0.41	0.31

* *T*-statistic in parentheses.

** Standard errors corrected for heteroskedasticity.

rates are independent of the period employed; thus the gathering contracts are not really permanent in nature with a premium for tenure. As expected, both Village B and Village C residency are associated with lower incomes than the omitted Village A.

Further decompositions of OLS differentials are available using various forms of the Oaxaca method listed in Eqs. (3a,b,c). The cross-contract earning differential in Table 1b of 0.35 log points can be decomposed into that attributable to payments on the gatherers' productivity characteristics and that attributable to differences in the wage structure. In the first column of Table 5, differences in gatherer endowments of income generating

Table 5

Decomposition of relative payment–piece-rate log wage differential

Difference in mean log wages:	0.346		
Difference due to:	Evaluated at	Evaluated at means	Cotton method
	piece-rate means	relative payment	
Wage structure ^a	82% (0.28)*	39% (0.13)	60% (0.21)
(Relative payment advantage) ^b			20% (0.07)
(Piece rate disadvantage) ^c			40% (0.14)
Gatherer characteristics ^d	18% (0.06)	60% (0.21)	40% (0.14)
Literacy	0.006	0.1	0.01
Experience	0.007	-0.04	-0.02
Age	0.028	-0.01	0.01
Days worked	0.012	0.02	0.02
Village B	0.185	0.23	0.21
Village C	-0.176	-0.01	-0.09

Source: Results from Table 4 and data set sub-sample means.

^a $X_r(B_r - B_p)$ or $X_p(B_r - B_p)$.^b $(B_r - B^*)X_r$.^c $(B^* - B_p)X_p$.

^d $B_p(X_r - X_p)$, $B_r(X_r - X_p)$, or $B^*(X_r - X_p)$, where B_r and B_p are the relative payment and piece-rate wage structures and B^* = a non-discriminatory wage structure created from the weighted average of the subgroup wage structures B_r and B_p .

* Figures in parentheses are log point differences in daily earnings.

characteristics are evaluated at the piece-rate pay structure. Worker characteristics explain a small portion of the wage differentials. The remaining portion is the difference that a worker with “piece-rate” type income-generating characteristics would earn just due to working under relative payments.

The second and third columns of Table 5—evaluating the difference in contractual earnings at the relative payment means and using the intermediate Cotton method to impute a wage structure in the absence of market imperfections—are quite close. They suggest about half of the differences in daily wages are due to differences in worker productivity attributes, yet a significant amount—40%—is due to the higher contractual pay structure of relative payments and other unobservable factors. The relative payment productivity characteristics of those gatherers are overvalued by about 20%, while those of the piece-rate characteristics are undervalued.

In other words, gatherers with all types of inherent endowments should receive more on average under a relative payment wage structure. Continuing with the contractual subgroup analysis, it was found that the expected daily wages of workers with “piece-rate-type endowments” was 21.62 lps. under the piece-rate pay structure compared to 28.63 lps. under relative payments. Gatherers with “relative payment-type endowments” had expected daily wages of 30.46 lps. under relative payments compared to 26.64 lps. under piece rates. Those with relative payment-type endowments always earn more, and all types of gatherers would earn more under a relative payment contract.

The fact that some part of earnings differentials can be attributed to contractual rents raises the question of how gatherers ended up in the more remunerative relative payment contracts. A joint selection-earnings model was estimated using FIML methods following the standard Heckman technique. The (reduced form) probit model of gathering contracts in Table 6 is highly significant and successful in predicting 98% of the observations. Village effects dominate the sorting process, with gatherers in village B less likely to work in relative payments and those in village C highly likely, as compared to the omitted Village A where both contracts are very common. Recall that Village C is that most associated with conflictive property rights relations and high unemployment; this suggests that part of the rationale for efficiency wage contracts does relate to employers’ need for social control rather than an assured labor supply in a tight market.

The table shows that literacy plays a role in sorting workers into the relative payments scheme.¹⁰ Another form of human capital—years of gathering experience—is also significant. Relative payment work is associated with a greater number of gathering days across the year. Gatherers who desire more flexibility with their time may opt for piece-rates. The landholding variable is included as a signal of increased gatherer preference for piece-rates and a smaller likelihood of relative payment sorting. A unit increase in land access reduces the likelihood of relative payment work by 23%.¹¹

¹⁰ Since most observations only completed three years of formal schooling, literacy is the best proxy for education. In separate sub-sample regressions, the literacy variable was significant for gatherers working under piece-rates.

¹¹ Marginal effects in the probit model are calculated by multiplying the coefficients with a weighting factor, where the weighting factor is based on the standard normal pdf: $\phi(\Sigma B' X)B$, with X as the variable means.

Table 6
Selection and daily wage differentials by contract

	Probit sorting process		Selectivity-corrected earnings		
	Coefficient	Marginals	Pooled	Relative payment	Piece-rate
Constant	-1.84 (-0.72)*	-0.68	3.08 (24.05)	3.82 (21.20)	2.83 (16.08)
Literacy	-1.70 (-1.65)	-0.62	0.13 (2.26)	0.06 (1.10)	0.10 (1.07)
Larva experience	0.76 (1.73)	0.28	0.05 (3.29)	-0.02 (-1.25)	0.09 (4.05)
Gatherer age	0.01 (0.29)	0.004	-0.002 (-0.76)	-0.007 (-2.48)	0.002 (0.40)
Days gathering	0.03 (2.10)	0.01	0.0009 (1.19)	0.0005 (0.64)	0.001 (0.89)
Village B	-2.64 (-1.2)	-0.97	-0.35 (-4.2)	-0.22 (-0.96)	-0.36 (-3.24)
Village C	4.42 (2.40)	1.63	-0.16 (-1.65)	-0.32 (-4.11)	0.04 (0.05)
Landholdings	-0.63 (-1.71)	-0.23			
Contractor kin	1.80 (2.00)	0.66			
Contractor markets	-1.34 (-2.96)	-0.50			
Relative payment			0.19 (1.70)		
σ			0.27 (16.44)	0.18 (7.15)	0.30 (8.50)
ρ			-0.04** (0.001)	-0.68 (-0.71)	0.09 (1.08)
Sample size	105		105	52	52
Log-likelihood	-9.15		-20.09	-6.74	-3.31
Chi-squared (<i>df</i>)	127.26 (9)				
Adjusted R^2			0.42	0.41	0.30

* *T*-statistic in parentheses.

** The coefficient on λ was not significant in any case.

The use of kinship ties to avoid moral hazard is common in fishing activities (Doeringer et al., 1986). Yet it is unclear if workers with higher levels of this social capital should be found under relative payment and piece-rates since these contracts themselves are meant to solve moral hazard problems.¹² Here workers with kinship ties—a gatherer having a relative who is a contractor—are 66% more likely to work under relative payment systems. Following Tunali (1993), information about the contractor matched to each gatherer is included as determining the type of contract used. The contractor's number of sales outlets measures whether the contractor makes exclusive sales to a large exporting farm in the on-call system (linked to relative payments) or not. For each extra sales outlet that a contractor uses, gatherers are 50% less likely to be paid using relative payment incentives.

The selectivity-corrected daily earnings regressions in Table 6 still present a premium due to relative payment work per se.¹³ The dummy variable for relative payment contracts still increases income by almost 20%, again demonstrating the earnings premium for this

¹² Family kinship networks can reduce the moral hazard problem between contracting parties; kinship ties could provide signals about a prospective employee's latent aspects and likelihood of giving higher effort and care on the job (Platteau and Nugent, 1992). Other literatures, however, have suggested that kinship ties are not associated with greater worker productivity and serve merely as an exclusive sorting device (Assaad, 1997).

¹³ Alternative specifications were tried on the second-stage earnings regression to include days worked, kinship, and other variables. In each case the coefficient on relative payment contracts remained above 15%, although these extra variables were highly correlated with the relative payment dummy, and the significance of the village and literacy variables was reduced.

contract. Although the separate earnings regressions by contract were significantly different using a Chow-test,¹⁴ it appears the relative payment contract workers receive a higher fixed bonus rather than higher returns on their endowments. The dummy variable on literacy shows this attribute raises wages by about 18%, while residents of Villages B and C have lower wages in general. The other coefficients are quite close to those estimated under OLS. This is not surprising since there was little evidence of cross-equation correlation of the unobserved variables.¹⁵

Further decompositions demonstrate that contractual outcomes and earnings differentials vary little across sub-groups of gatherers with different productivity attributes. Separate calculations of the wage differentials for each individual based on the estimated coefficients in Table 6 show that 87% of the whole sample would earn more under the relative payment pay structure. These differentials are positive for all sub-groups of people. Levels of gathering experience present the only anomaly; more experienced gatherers (with five or more years work) would earn more under the piece-rate structure. This may be due to this group being slightly older and land-endowed so that they enjoy the flexibility of the piece-rate system.¹⁶

5. Conclusions

The basic thrust of the agrarian contracts literature has been to explain how labor arrangements deal with information, risk-bearing and credit access imperfections. Few empirical studies have addressed the distributional impacts of efficiency wage contracts, and relative payments in particular. This paper shows that although both piece-rates and relative payments provide incentives for self-supervision (and perhaps social control), the relative payment contracts may contribute to involuntary unemployment and an efficiency wage premium. A contractual earnings gap for relative payments is consistent with the incentive-compatibility mechanism and the profit maximization goal of contractors.

Various statistical tests were used to examine these trends in the earnings distribution of a Central American petty extraction economy. The gathering activity is difficult to supervise, and the production setting is characterized by conflictive property rights changes. Both piece-rate and relative payments contracts have emerged in the contractor–gatherer relationship. There is a higher level of overall income inequality in the community where relative payment contracts are most common, and there is a correlation between working under the relative payments contract and being higher ranked. The different methods used in Tables 1b, 4 and 5 all demonstrate a naive wage gap of 35% between gathering contracts, of which at least 40% may be attributed to “contractual

¹⁴ The *F*-statistics was 2.54, compared to a 95% significance level of 2.04 for (9, 87) *df*.

¹⁵ In two-stage least squares estimates the selectivity-correction term (λ) was positive and weakly significant in the piece-rate equation but not different from zero under relative payments.

¹⁶ The cross-correlation between experience and age for the whole sample was 0.02, yet 0.07 for the high experience group. The correlation between experience and landholdings was 0.12 for the sample and 0.66 for high.

rents” and other unobservables. The 20% premium to the relative payment contract per se occurs even after controlling the joint determination of contract choice and earnings. It appears that most gatherers would prefer to work under the relative payment system since they would receive a higher daily wage.

Thus it may be concluded that relative payment contracts with a firing penalty for self-supervision are not distribution-neutral. The empirical results show a worsening intravillage income distribution in those areas where multiple contractual arrangements exist. The use of these efficiency wage contracts could have broader path dependence implications. Such contracts may foster an economic environment favoring their continuance as the incentive for self-supervision is heightened through the reality of involuntary unemployment and an increasingly unattractive reservation wage. Extending the links between property rights, farm structure, changing reservation utility levels, and the endogeneity of contractual design into a general equilibrium framework is a topic for further research. Likewise, study of the implications of contractual design for rural income distribution across a wider-range of extractive economies is needed.

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Appendix A. A model of contractual choice and earnings differentials

Consider a gathering setting in which costly monitoring and enforcement are outstanding problems. Gatherers are of equal ability but work unsupervised across a wide area. The interrelated random common shock (θ) and the gatherer’s effort (e) create moral hazard. Factors such as regional rainfall, water temperature, and the lunar cycle are encompassed in the additive shock θ , with $E(\theta)=0$. The distribution of the environmental shocks is assumed to be independently and identically distributed across each period, implying no intertemporal decline in work productivity due to overextraction.¹⁷ Following the common specification of Green and Stokey (1983) and Malcomson (1984), the catch “ q ” of each representative gatherer is an additive function of human effort and the natural environment:

$$q = f(e) + \theta \quad \text{or} \quad q = x + \theta \quad (4)$$

where x_i is a random variable depending on the true effort.

¹⁷ This assumption is realistic for some natural resources (such as rubber, shrimp and some fish species) in which habitat trends affect the product stock more than human effort (on the larva case, see Smith and Panayatou, 1984).

“ E ” is a continuous variable representing the true gathering effort, or “effort intensity”, applied during a work period. There is a minimum effort level \bar{e} (such as showing up for work) that the principal can verify, but further work effort in remote gathering spots is unseen. “ X ” is the principal’s perception of gathering effort measured in visible time units. Although gathering outputs are correlated, the contractor-principal cannot statistically measure the effect of θ on quantity nor separate its impact from true gathering effort.¹⁸ Thus the principal uses quantity to make a subjective assessment of each gatherer’s work effort, subject to error.

Gatherers receive private, varying, signals about the common shock and decide whether or not to supply a high level of effort above \bar{e} . Gatherers value wages positively and effort negatively, and gatherers adjust their effort levels in response to the relative expected wages from gathering “ w ”. Extraction is probabilistically related to the unobserved effort and the environment so $q_{e\theta} \neq 0$.¹⁹ Thus the specification of effort choice is $e = e(w, \theta)$.

The gatherer’s expected utility function is strictly increasing, concave, and separable in income and effort:

$$\begin{aligned} \text{Max}_e \text{EU} = \text{EU}(w(q(e, \theta)), e) \text{EU}_w > 0, \text{EU}_e < 0, \text{EU}_{ww} \leq 0, \text{EU}_{we} \\ \geq 0, \text{EU}_{ee} \leq 0 \end{aligned} \quad (5)$$

with $\text{EU}_w w_q q_e + \text{EU}_e = 0$.

The general solution to the utility maximization problem includes the negative disutility of effort and a positive component of the marginal utility of effort multiplied by how effort affects the quantity of a product and how the product quantity affects wages. Utility differentials cannot be verified directly, but indirect inference can be obtained by comparing contractual-specific earnings across households if there are no compensating differentials of employment across the different contracts.²⁰

¹⁸ More formally, Malcomson (1984) and Green and Stokey (1983) define a probability density function for implied effort in q and x given true effort e which can be written as: $f(x - e)$. $F(x - e)$ is the cumulative distribution function. This implies that the actual effort observed through quantity, and by default x , becomes a random variable whose distribution depends on the true effort level. For simplification only one variable is assigned for the effort term.

¹⁹ Effort enhances the amount of gathered product, but at a decreasing rate: $f_e > 0$, $f_{ee} < 0$. The normal properties of the cumulative distribution function (First-Order Stochastic Dominance, the Monotone Likelihood Ratio Property, and the Convexity of the Distribution Function) are assumed to hold on the distribution of q . These are logical since increasing levels of effort provide a higher probability of observing a high quantity. And the observation of higher catches allows the contractor infer the gatherer supplied more effort.

²⁰ Compensating, non-pecuniary, differentials with divergent effort requirements should not persist since workers are doing the same activity in the same working conditions, only under different payment forms. In the present case study, households interviewed were indifferent between the physical requirements of gathering and other activities in the labor market (such as cattle-tending, agriculture, and shovelling in salt ovens).

The profit function of the risk-neutral contractor likewise is strictly increasing. Assuming away other operating costs and a product price normalized to one, the profit function generally maps the difference between sales and the wage paid to gatherers:

$$\text{Max}_w \Pi = E[q] - w = E[z + \theta] - w. \quad (6)$$

A.1. Relative payment schemes

Contractors in a relative payment scheme can use ordinal ranking to deduce information about the general condition of the covariate environmental shock θ and the relative effort of each gatherer. To operationalize the relative payment system, assume an unwritten, quantity-based performance rule exists: gatherers bringing in product amounts below a cut-off are not invited back to work with the contractor in the next and subsequent periods. The principal sets a proportion ψ to retain in the next period and a proportion $(1 - \psi)$ to fire. This two-period contract mimics an extreme internal promotion and demotion scheme.

Contractors always count the catch returned by each gatherer, and ordering the catch levels offers a low-cost method of acquiring information about the worker's behavior and the natural environment.²¹ The ex-ante ranking cut-off proportion inherently is a function of a target quantity level q^* which the contractor chooses simultaneously with the wage levels.²² The proportion ψ retained is verifiable by the gatherers ex-post so there is no falsification of the ordering and the contract is enforceable. And since the proportion ψ retained is related to the top of the distribution, gatherers have an incentive to increase work effort. This is particularly true when any such promotion probability lies strictly between 0 and 1 (Malcomson, 1984).

The relationship between ψ and effort works through how a gatherer's effort affects his or her quantity and how that quantity compares to that of other gatherers: $\psi_e = \psi_q q_e$. Effort enhances the retention probability, but at a decreasing rate: $\psi_e > 0$, $\psi_{ee} < 0$.²³ Since the effects of the common shock θ on the relative payment disappear (Nalebuff and Stiglitz, 1983), the yield differential between gatherers relates to variation in effort.

A superscript "R" represents a simplified two-period relative payment wage package. Since second-period effort affects third-period earnings in a similar fashion, it is not

²¹ This contrasts some strands of the sharecropping literature in which the principal must choose an optimal level of supervision costs to determine whether a worker is supplying a minimal level of effort (Otsuka et al., 1993).

²² This is equivalent to specifying a critical value of x^* if effort were observable. Actually ψ now incorporates the cumulative distribution function on target quantity, and thus effort: $\psi = 1 - F(x^* - e_i)$, with $F(x - e)$ as the cumulative distribution function of observed quantity and a probability density function $f(x^* - e_i)$ as the marginal effect of effort on retention.

²³ All authors within the relative payment literature also assume that a Cournot–Nash solution is reached with each player optimizing (working hard) against the effort investment of his or her opponent. The probability of winning is symmetric so a pure Nash solution exists.

modelled explicitly.²⁴ While paid a fixed wage of B_1 in the first-period (subscript 1), the gatherer's wage in the second period (w_2^R with subscript 2 for second period) is based on comparing his or her first-period performance to that of other gatherers. Written explicitly, this means:

$$w_1^R = B_1 \quad w_2^R = f(\psi(q(e_1(B_2)))) \quad (7)$$

The reward structure thus involves the prize of winning job retention and the penalty of losing as being fired. If successful, the gatherer earns B_2 in the second period; if not, the gatherer earns only his or her reservation wage w_0 with $\bar{U} = U(w_0, e)$. The second period prize, B_2 , can either be the same as the earlier wage ($B_1 = B_2$), or it may be a different fixed wage set above some critical subsistence minimum "s" to reflect the minimum "arriving on the job" effort \bar{e} ($B_2 \geq s$). Note that in the last, second, period gatherers logically supply only \bar{e} since no further promotion (or bequest) is possible at that stage. The first-period effort supply function now is represented by: $e_1 = g(B_1, B_2, w_0, \psi)$.

The two-period relative payment wage package is represented by:

$$w^R = w_1^R + w_2^R$$

$$w^R = B_1 + r[\psi(B_2) + (1 - \psi)w_0] \quad \text{where } r = 1/1 + d. \quad (8)$$

The total two-period wage is influenced by the fixed wage level, the probability of job retention ψ , the discount factor r , and alternative reservation wages w_0 .

Assume the utility is additively separable across periods so $EU(e_1, w_1, \bar{e}, w_2) = U_1(e_1, w_1) + EU_2(\bar{e}, w_2)$. Substituting the wage equation into the utility function, the gatherer chooses first-period effort to maximize utility:

$$\text{Max}_{e_1} EU^R = U(B_1, e_1) + r[\psi EU(B_2) + (1 - \psi)\bar{U}] \quad (9)$$

$$\text{s.t. } e_1 \geq \bar{e}.$$

The gatherer's first-order condition on the effort choice becomes:

$$EU_e + r\psi_e(EU(B_2) - \bar{U}) = 0 \quad (10)$$

Eq. (10) means that the gatherer compares the marginal disutility of present effort against increasing the probability of job retention and the discounted benefits of future gathering work through its premium over other employment. As the present disutility rises, or the gatherer's discount factor falls (with a higher discount rate δ) and effort effectiveness fall, an increasing future wage premium is needed. $e^{*R} = e(B_2, \theta)$ solves Eq. (10) to represent the optimal effort first-period level under the relative payment contract, with $e_B^{*R} \geq 0$. Since $U_e < 0$ and $U_w > 0$ an interior solution exists for e_1 only if $EU(B_2) > \bar{U}$

²⁴ The infinite or multi-period setting is simplified by reducing payments to a two-period scheme (Malcomson, 1984; Banerji and Rashid, 1996).

(Malcomson, 1984). If B_2 just equals w_0 the gatherer supplies \bar{e} so the contractor is not maximizing profits.²⁵ This result derives mainly from the fact that there are no share payments to the gatherer.²⁶

The contractor's problem is to maximize profits subject to the agent's reservation utility (participation) and incentive compatibility constraints. For the case of relative payments with a firing penalty, the contractor's problem with each gatherer is to choose the fixed wages B_1 and B_2 , the retention probability ψ (and by default the cut-off q^*):

$$\max_{B_1, B_2, \psi} \pi^R = E[z + \theta] - B_1 + r\psi[f(\bar{e}) - B_2] \quad (11)$$

$$\text{s.t. } U(B_1, e_1) + r[\psi EU(B_2) + (1 - \psi)\bar{U}] \geq \bar{U} + r\bar{U}$$

$$\text{s.t. } r\psi_e(EU(B_2) - \bar{U}) = -EU_e$$

$$\text{s.t. } B_1 = B_2.$$

Here if the first, participation, constraint is binding, the principal/contractor just pays a wage giving utility equivalent to agent's reservation level. The second incentive compatibility constraint incorporating the gatherer's first-order condition equates the disutility of effort against the benefits of hard work. Fixed wage equivalency across periods is taken as a cultural norm in the third constraint; this is because there are likely high transaction costs in the negotiations between contractors and gatherers in determining the actual timing of period one and two at any given month for any given gatherer boat.

But the contractor's logical choice of the fixed wages and retention probability leads to a relative payment equilibrium in which the participation constraint is not necessarily binding. Malcomson (1984) has proven that a principal can maximize profits by offering a contract combining a non-trivial retention probability and wage package in which the earnings of retention must be greater than those from being fired (i.e. $B_2 > w_0$). This is optimal when the agent's second-period marginal utility of income is sufficiently large relative to the rate at which the marginal disutility of first-period effort increases. Indeed with a unimodal probability density function and a range of constant relative risk aversion utility functions, it can be shown that, specifically, the retention probability must lie below 1/2. Under risk neutrality of the agent, the results are ambiguous, suggesting the need for empirical testing.

In the specification of Eqs. (8)–(11) with the assumption of similar fixed wages across time ($B_1 = B_2$), higher wages are paid every period. If the model were extended to a multi-period framework, a retention bonus would exist in all subsequent periods. Dropping the constraint of wage equality across periods in Eq. (11) and adopting a constraint that wage

²⁵ Malcomson (1984) discusses this point in a proof of Lemma 3, and a graphical discussion of a similar constrained maximization problem is provided in Bardhan (1984, p. 109).

²⁶ The models of Shapiro and Stiglitz (1984) and Eswaran and Kotwal (1985) also require overpayment to permanent laborers in each period since there are no share residuals.

levels are just equal or greater than a subsistence value “ s ” ($B_1, B_2 \geq s$) change the result slightly. Second period wage differentials are expected, but the equilibrium value of B_1 would not entail enforcement rents.

A.2. Piece rates

Gatherers paid piece-rates receive a share of the final price for each unit of product delivered. Assume the same production technology and effort response function as above. Payment is through a share parameter α , which is determined in part by the expected quantity of gathered product and the opportunity wage. A positive or negative side-payment B usually is determined with the share to render agents ex-ante indifferent between gathering and other employments.

Following the classic specification of sharecropping (Stiglitz, 1974), wages in a one-period, one-gatherer piece-rate contract with a superscript P are described as:

$$w^P = aq(e, \theta) + B \quad (12)$$

where a = the share or price paid per piece; B = a fixed (positive or negative) wage term; e , q , θ as above.

A one-period wage contract ensues. Each gatherer chooses “ e ” to maximize expected utility over each period:

$$\text{Max}_{e_1} \text{EU}^P = \text{EU}(a(f(e_1, \theta)), B, e_1). \quad (13)$$

In the multi-period framework, the same contract is repeated each period, with the contractor meeting the reservation wage constraint to encourage future participation. Since the first-period effort only affects first-period earnings, the gatherer’s necessary first-order condition on effort e becomes:

$$\text{EU}_w(af'(e, \theta)) + \text{EU}_e = 0. \quad (14)$$

The gatherer balances the benefits of effort (the marginal utility of income from the gatherer’s share of the product) against its cost in disutility terms. $e^{*P} = e(\alpha, B, \theta)$ solves Eq. (14) to represent the optimal effort under the piece-rate contract, with effort responding positively to changes in the share parameter: $e_a^{*P} > 0$ (Bell, 1989).

The contractor maximizes profits by selling the gathering product and deducting the piece rate share due to the gatherers. The contractor chooses α and B subject to the gatherer’s reservation wage participation constraint and the incentive compatibility condition:

$$\max_{\alpha, B} \pi^P = E[f(e_1(\alpha, \theta))(1 - \alpha)] - B \quad (15)$$

$$\text{s.t. } \text{EU}(\alpha q_1, B, e_1) \geq \bar{U}$$

$$\text{s.t. } \text{EU}_w(af'(e_1, \theta)) \geq -\text{EU}_e.$$

A common result is that the contractor can choose α and the (positive or negative) B just so the agent's reservation utility is met (Singh, 1989; Mitra, 1983). The participation constraint must be binding if the tenant has constant or decreasing absolute risk aversion (Bell, 1989).

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