Payments Under the Table and Tax Distortions: Implications for Optimal Taxation

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Abstract

I develop a model of optimal income taxation that incorporates a hybrid employment structure, where formally employed workers receive both recorded wages and payments under the table (PUT). When firms' choices are not considered, the optimal tax rate depends on two sufficient statistics—the PUT elasticity and the ratio of PUT to reported wages—both of which shape the trade-off between redistribution and efficiency. A higher absolute value of the PUT elasticity lowers the optimal tax rate, as even a small tax increase induces a large shift toward unreported wages, raising efficiency costs. Similarly, when PUT constitutes a larger share of reported income, tax distortions become more severe. When firms are introduced, the corporate tax creates an additional distortion because PUT wages cannot be deducted from taxable income. As higher PUT wages reduce income tax revenue, they simultaneously increase corporate tax payments, partially offsetting the revenue loss and affecting redistribution. I apply this model to the Peruvian context. To estimate PUT, I perform optimal transport matching between two datasets that most governments already collect—payroll administrative records and household survey data. I find that PUT are widespread across the Peruvian economy, with 43% of formally employed workers receiving part of their salaries this way. Using these estimates, I show that when PUT responses are considered, the optimal tax rate for Peru should be lower than its current level.

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1. Introduction

Traditionally, labor informality has been considered a binary status, where workers are either formal—registered on the payroll of a firm and thus covered by social security—, or informal—not registered on the payroll of any firm and receiving their entire salaries off the books. The latter are not registered anywhere. This dichotomy suggests that registered employees may be subject to taxes, while informal employees are not.

However, especially in developing and middle-income countries, the concept of labor informality is not as straightforward as a binary status. Rather, it exists on a continuum, with some employees falling into a partially-formal category. These workers are registered on a firm's payroll—necessary condition to be considered formal—but also receive additional salary off the books. As a result, such workers may be subject to payroll and income tax, but only on the portion recorded on the firm payroll and thus reported to the tax authorities. In this study I define these additional payments as payments under the table (PUT) following Feinmann et al. (2024, 2025). These are also called envelope wages.

PUT are a widespread phenomenon among formal workers in Latin America. A multi-country survey conducted in Argentina, Brazil, Chile, Colombia, Mexico and Peru finds that 17% of formal employees report receiving a portion of their salary under the table, with an average of 24% of their earnings paid off the books. The survey further reveals that PUT is more common among high-income workers, men, and individuals in managerial positions, and is particularly prevalent in smaller firms. This phenomenon goes further than just Latin America. For instance, Biro et al. (2022) find that a significant portion of workers reporting minimum wage earnings in Hungary receive at least the same amount of income off the books. These findings reinforce the notion that PUT is not a marginal or isolated practice but rather a fundamental feature of labor markets in developing economies.

Despite this, the public finance literature has yet to explore the implications of the prevalence of PUT for tax efficiency and redistribution. When workers receive a portion of their salary under the table, the firm benefits from reduced payroll tax liabilities, while the worker avoids higher marginal income tax rates. In effect, the worker and the employer realize joint tax savings. Furthermore, there are also costs for the firms in foregone deduction of the corporate tax as payroll expenses are typically deductible for corporate taxation purposes. In this paper, rather than framing these arrangements as 'collusion' or 'cooperation', I focus on the net benefit—i.e., the combined tax savings from both sides—and assume that, through bargaining, this surplus is split in such a way that workers may willingly accept a lower officially reported wage in exchange for some of the income being treated as PUT.

As PUT can affect both the revenue-raising and redistributive potential of the tax system, this study addresses two key research questions: (i) what is the impact of PUT on the efficiency and redistributive potential of the income tax? and (ii) how do these payments affect the optimal income tax? What are the sufficient statistics needed to characterize this optimal tax system?

I examine these questions in Peru, a middle-income country with a significant informal sector.[1] To answer the research questions, the first step is to identify PUT in the economy. To do so, I perform an optimal transport matching between two datasets that most governments already collect: the payroll administrative dataset and the household survey. I assume that, below a specific (very) high-income threshold, the wage distribution observed in the survey represents the true distribution. Under this assumption, I construct a restricted statistical matching between the two sources, where each registered worker in the payroll dataset is paired with a similar worker in the household survey, with the survey wage assumed to be the 'true' wage plus measurement error. The difference between the matched wage and the reported wage in payroll records is then interpreted as PUT plus measurement error. I find that PUT exists across the entire income distribution and that its magnitude increases with income levels. On average, the estimated PUT amount is roughly equivalent to the difference between the minimum wage and reported wages.

The second step of this study is to develop a simple model of a labor market where workers decide whether to receive part of their wages under the table and, if so, how much. The wage they receive under the table is higher than the net-of-tax fully formal wage but lower than the before-tax fully formal wage. This is consistent with workers and firms sharing the net benefits of this arrangement. A social planner sets a linear income tax for all workers earning wages above a threshold. If we consider this problem only from the worker's side, the optimal income tax is similar to the standard top income tax formula. However, two additional components must be taken into account. First, the elasticity of taxable income explicitly includes a PUT elasticity, which captures the intensive-margin response of PUT to changes in the net-of-tax rate. The higher this elasticity, the lower the optimal tax rate. Second, the ratio of PUT to reported wages plays a role similar to the Pareto parameter in the top income tax formula: the larger the share of PUT in reported income, the greater the associated distortion, leading to a lower optimal tax rate. In this worker-only framework, the key sufficient statistics are the PUT elasticity and the ratio of PUT to reported wages.

However, when firms are included, these same statistics continue to play a central role

[1] Approximately 70% of the labor force works entirely off the books, meaning they are not registered on any firm's payroll and that firms do not contribute to social security for them. These fully informal workers are not part of my sample of interest. However, the widespread presence of labor informality suggests that even registered formal workers may be more inclined to engage in PUT arrangements. The same structural conditions that allow high informality—such as the low perceived value of social security benefits, weak tax enforcement, and employer flexibility—may also encourage partially informal wage arrangements among those officially employed.

but with additional redistribution considerations. The next step is to extend the model to include firms, where an additional redistribution channel emerges through the corporate tax treatment of PUT wages.

A key feature of payments under the table (PUT) is that they require coordination between workers and firms, making firms' decisions an integral part of the analysis. This contrasts with the classical case of under-reporting by workers alone and has implications for wage equilibrium—specifically, the differences between fully formal wages, PUT wages, and net-of-tax formal wages. These wage gaps determine how the net benefits of under-the-table payments are shared between firms and workers. To capture this, I extend the model to incorporate firms and general equilibrium wage determination. Notably, even with firms, the sufficient statistics for the optimal income tax remain the PUT elasticity and the ratio of PUT to reported wages. The main distinction in this extended model is that redistribution now includes a corporate tax-PUT component: when wages are paid under the table, firms cannot deduct them from their taxable income, creating a revenue-PUT channel where higher PUT wages lead to higher corporate tax payments. An increase in the net-of-tax rate induces two opposing effects—it raises after-tax wages, incentivizing labor supply, but also reduces wage shifting to the PUT channel, thereby expanding the tax base. If the absolute value of the PUT elasticity exceeds the labor supply elasticity, the revenue gain from reduced non-deductibility dominates, increasing net revenue, whereas if labor supply responses are stronger, the efficiency cost may outweigh the revenue benefit.

Theoretical public finance models have long suggested that firms and employees may underreport wages to reduce their tax liabilities (Yaniv, 1992). Such practices, however, are relatively rare in developed countries, primarily due to robust third-party reporting mechanisms. Kleven et al. (2016) provide a seminal contribution to this literature, proposing a framework where collusion is effectively deterred by the presence of accurate business records and third-party reporting—features that are typical of modern, large firms. However, they also acknowledge that such collusion is more likely to persist in small firms, where monitoring is limited, and informal agreements are easier to sustain[2].

Empirically and besides the above-mentioned surveys, most documented cases of wage underreporting and tax evasion are found in developing countries without third-party wage income reporting mechanisms, as shown in studies like Kumler et al. (2020) for Mexico and Bergolo and Cruces (2014) for Uruguay. In contrast, firms and employees in Peru are subject to third-party wage reporting (the basis of my data). Thus, this paper seeks to identify the conditions that permit sustained tax evasion despite the presence of third-party

[2]Bjørneby et al. (2021) documented wage underreporting and collusive tax evasion in small firms in Norway, despite extensive third-party reporting and withholding taxes

enforcement mechanisms. To my knowledge, this has not yet been studied, making this the main contribution of my study.

Beyond contributing to the public finance literature, this study also advances the labor economics literature by proposing a method to identify PUT using labor market data. This approach moves beyond the traditional binary classification of formal versus informal employment, offering a nuanced framework that can be a valuable tool for future research on labor market dynamics and tax compliance.

From a policy perspective, addressing the issues raised in this study is particularly relevant, as PUT represents a significant yet under-explored source of potential government revenue. Identifying and taxing PUT could increase fiscal revenue without imposing additional burdens on low-income individuals. This would enhance the efficiency of the income tax system while minimizing adverse effects on vulnerable groups, aligning with redistributive goals.

The document is structured as follows: Section 2 provides a detailed overview of the income and corporate tax systems in Peru. Section 3 describes the datasets used for the analysis. Section 4 explains the methodology employed to estimate PUT. Section 5 introduces the labor market model that incorporates PUT and analyzes the optimal income tax in this setting.

2. Tax System in Peru

This section examines Peru's tax system, particularly its relationship with payments under the table (PUT), which are often employed to evade taxes. Table 1 summarizes the income and corporate tax systems in relation to the minimum wage.

Personal Income Tax. Wages paid to employees in Peru are subject to personal income tax and payroll taxes. Peru's personal income tax system is progressive and calculated on an annual basis. Workers earning less than seven tax units (UIT) are exempt from paying income tax.[3] Seven tax units correspond to 2.5 times the annualized minimum wage. Earnings beyond this threshold are subject to progressive tax rates as follows: 8% for the first 5 tax units (up to 4 times the minimum wage), 14% for amounts from 5 to 20 tax units (equivalent to 9 times the minimum wage), 17% for amounts from 20 to 35 tax units (equivalent to 14.5 times the minimum wage), 20% for amounts from 35 to 45 tax units (equivalent to 18 times the minimum wage), and 30% for any excess of the income.

[3]For 2021, one tax unit (UIT) was equivalent to 4,950 Peruvian soles (approximately $1,250).

Table 1: Income and Corporate Taxes

	Personal Income Tax	Payroll Tax		Corporate Tax
		Pensions	Health Care	
	(1)	(2)	(3)	(4)
Individual Income:				
$[\bar{w}, 2.5\bar{w})$	0%	13%	9%	
$[2.5\bar{w}, 4\bar{w})$	8%	13%	9%	
$[4\bar{w}, 9\bar{w})$	14%	13%	9%	
$[4\bar{w}, 14.5\bar{w})$	17%	13%	9%	
$[14.5\bar{w}, 18\bar{w})$	20%	13%	9%	
$18\bar{w}+$	30%	13%	9%	
Firm Profits:				
0				0%
>0				29.5%
Levied on:	Workers	Workers	Firms	Firms

Note: The minimum wage ($\bar{w}$) in 2021 was 930 Peruvian Soles per month for full-time work.

Payroll Taxes Payroll taxes in Peru consist of contributions to pensions and public health care, levied on employees and employers, respectively. Employers are required to contribute 9% of their employees' salaries to the public health care system (EsSalud), which provides universal access to health insurance to the worker and dependents, regardless of their income level.

Furthermore, workers have to contribute 13% of their salary to their pensions. Workers can voluntarily choose between them: the public pension system (SNP) and the private pension system (SPP). The public pension is a defined-benefit plan where employees contribute 13% of their salary to finance the system. Workers are eligible for a pension after completing 20 years of contributions and reaching the age of 65. The system provides a minimum monthly pension half the minimum wage for workers earning the minimum wage and a maximum pension of the minimum wage for workers earning twice the minimum wage or more. The private pension is a defined-contribution system in which employees must contribute 13% of their salary to individual savings accounts. Upon retirement at age 65, the pension amount is determined by the accumulated savings, and there is no lower or upper limit on benefits. Upon starting a new job contract, workers can choose freely between the public and private pension (but the default is the private one), with the key difference being that the public one guarantees a fixed pension amount, while the private one links pension benefits directly to the worker's contributions and investment returns.

Corporate Tax In Peru's general private regime, firm profits are subject to a corporate tax rate of 29.5%. Profits are defined as gross income minus expenses incurred to generate that income, including wages reported on the firm's payroll. Approximately 90% of formal workers registered in payrolls are employed by firms operating under this regime, which is the primary focus of this project. The current corporate tax system creates a clear distinction in incentives for firms regarding payroll reporting. Firms with positive profits have strong incentives to fully report payroll expenses. Since wages are deductible from gross income, reporting salaries reduces taxable profits and, consequently, the firm's corporate tax liability. Firms with zero or negative profits, in contrast, face no benefit from reporting wages, as there is no corporate tax liability to reduce. For such firms, paying wages under the table can be a cost-minimizing strategy, as it allows them to avoid payroll taxes without losing the benefit of tax deductions.

It is important to note that Peru has two additional special tax regimes designed for smaller firms. First, there is the SME Tax System, which applies to small and medium enterprises (SMEs) with profits not exceeding 1,700 tax units (approximately $2 million). Firms under this system pay a reduced tax rate of 10% on the first 15 tax units** of profit and the standard 29.5% rate on any excess. Second, there is the Special Income Tax System, which applies to microenterprises with profits under $150,000 and imposes a simplified tax rate of 1.5% on revenue rather than profits. However, this project does not focus on firms operating under these special regimes. The analysis instead centers on firms in the general private regime, as they employ the majority of formal workers and are the most relevant for understanding the interaction between payroll reporting, PUT practices, and corporate tax incentives.

Incentives to Pay Under the Table The tax system creates incentives for workers and employers to engage in PUT to minimize tax liabilities. Specifically, workers have no incentive to report earnings exceeding 2.5 times the minimum wage. Beyond this threshold, they become subject to progressively higher income tax rates, which significantly reduce their net earnings, while payroll benefits remain unchanged. In the public pension system, workers earning more than twice the minimum wage receive no additional retirement benefits, and employers in both systems incur higher costs without corresponding returns. Likewise, access to health care remains the same regardless of payroll tax contributions.

To minimize tax liabilities, workers may cap their formal income at this level and receive additional earnings as PUT. This distorts the labor market, as workers and employers collaborate to underreport wages and evade taxes. By receiving under-the-table payments above the exemption threshold, workers avoid personal income taxes entirely, while employers reduce payroll tax obligations. Rather than reporting full earnings, employers and employees negotiate to split the joint tax savings from reporting only part of the wage. Let w denote the true wage and $\bar{w}$ the recorded wage; the under-the-table component is $\textsc{put} = w - \bar{w}$. The net benefit from this arrangement, $S(w, \bar{w})$, captures tax savings for both the worker (lower marginal income tax) and the employer (reduced payroll tax), net of lost corporate tax deductions.

Formally, the arrangement is mutually beneficial if

$$S(w, \bar{w}) > 0.$$

Under this condition, I assume that bargaining between the worker and employer leads to surplus sharing, with the worker accepting a lower official wage in exchange for a portion of their pay being processed off the books.

3. Data

This section provides an overview of the datasets used to estimate PUT. Specifically, I rely on the administrative payroll dataset and the household survey.

Payroll Data. The first dataset used in this study is the administrative payroll data from the Peruvian Ministry of Labor. The dataset contains information on all formal labor contracts for each month in the country, including salary, hours worked, tenure, social security benefits, firm characteristics (location, tax regime, number of workers), and employee characteristics (sex, age, education). The data spans from 2010 and is publicly available since 2020, with around 5 million workers represented annually.

Household Survey (ENAHO). The second dataset is the National Household Survey of Peru (ENAHO), which contains information from households in all 25 regions of the country. The National Institute of Statistics has collected this data on an annual basis since 1990. The survey includes an extensive Work and Income Module that collects data on employment and income from individuals aged 15 and above. The module includes variables on activity status, hours worked, salary, social security benefits, and other relevant factors. Approximately 40,000 individuals respond to Module 500 each year.

I performed a data harmonization process between ENAHO and payroll to ensure that both datasets include the same set of workers. I removed fully informal workers from ENAHO as they would not be included in the payroll dataset. Informal workers are defined as those without pension provision from their employer. I also excluded public sector workers from ENAHO since the payroll dataset only includes information from private sector firms. Additionally, I removed part-time workers from ENAHO since the payroll dataset only contains information on full-time workers (those who work more than 20 hours per week).

Descriptive Statistics. The 2021 harmonized sample consists of 5.6 million full-time private employees in the payroll and 7,300 in the survey. The distribution of salaries for employees with different levels of education in 2021 is presented in Figures A1-A3. The orange line represents the payroll distribution, the black line represents the survey distribution, and the dashed line represents the minimum wage. For employees with less than secondary education, both distributions are similarly clustered around the minimum wage. For employees with a secondary education, the payroll distribution is concentrated around the minimum wage, while the survey distribution is slightly skewed to the right. Finally, for employees with higher education, the payroll distribution remains concentrated around the minimum wage, while the survey distribution is centered on a value above the minimum wage.

The salary behavior of employees in Figures 1 and 2 is expected as they are low-skilled workers and earning the minimum wage is common. However, the salary behavior of employees in Figure 3 does not match reality. In Peru, only 30% of the population completes higher education, and there is a high salary premium for achieving this level. The household survey data shows that workers with a bachelor's degree earn 50% more than those with only secondary education, while workers with a master's degree or higher earn 190% more than those with only a bachelor's degree. Despite this, the wage distribution of the payroll is concentrated around the minimum wage, indicating that most workers receive a salary around this amount and that there is no wage premium for higher education. An alternative explanation for this behavior could be that these employees are receiving part of their salary under the table.

Although administrative payroll data and household surveys provide broad perspectives on reported and self-reported wages, firm-side data remain incomplete. Firms could label PUT as 'other expenses' in their balance-sheet reporting. However, in my analysis, I conservatively assume that PUT cannot be deducted from firms' taxable income, implying that firms forgo corporate tax benefits. Because this assumption artificially raises the costs of paying under the table, the resulting estimates represent a lower bound on the true incentive to engage in PUT: if these payments can be successfully deducted, the actual cost of cooperation effectively falls to zero, making under-the-table arrangements even more attractive. Furthermore, many of the firms in this segment are relatively large and operate under the general tax regime, which subjects them to greater scrutiny. Yet if they still manage to classify these payments as deductible 'other expenses' without incurring sanctions, it reinforces the conclusion that the true incentives—and hence the prevalence—of under-the-table practices could be even higher than the current framework suggests.

Figure 1: Salary distribution of employees with less than secondary education, 2021

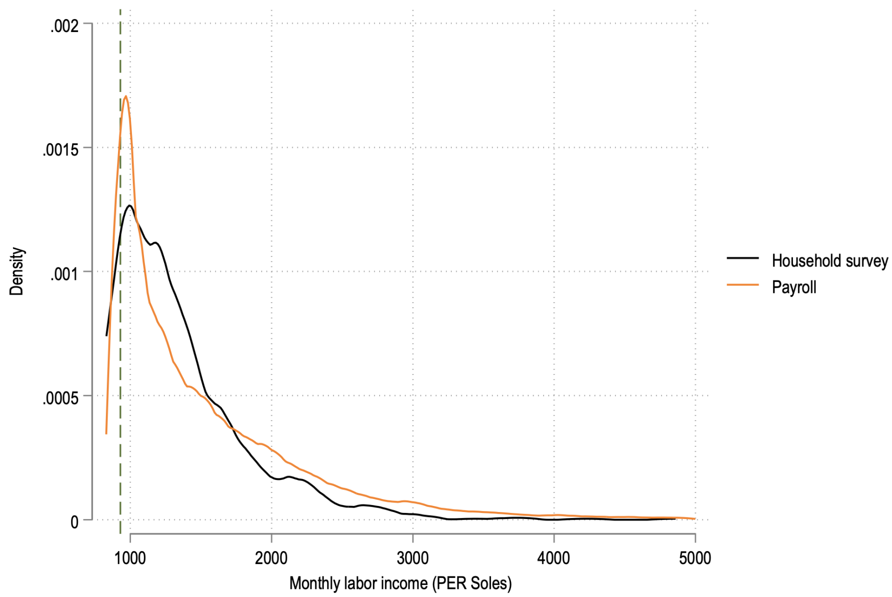
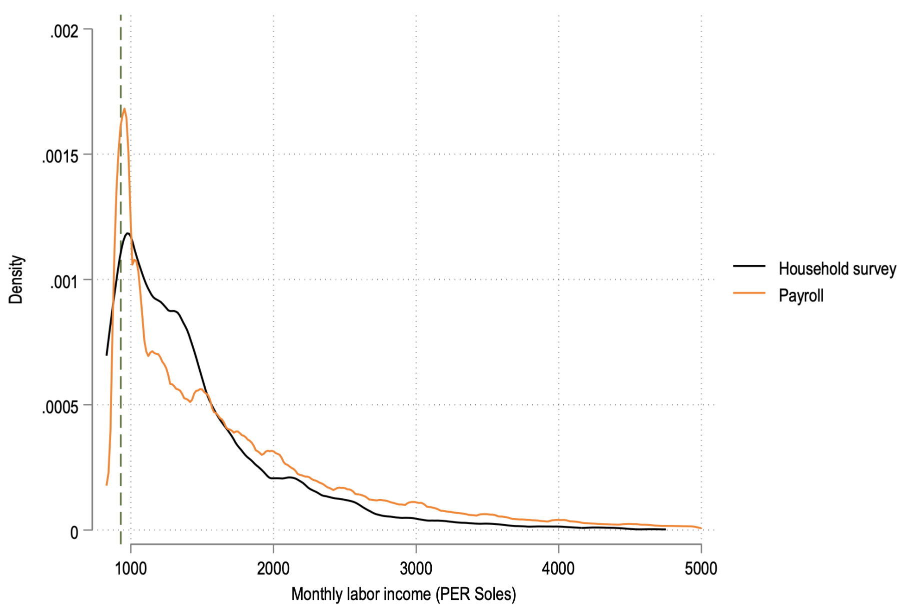


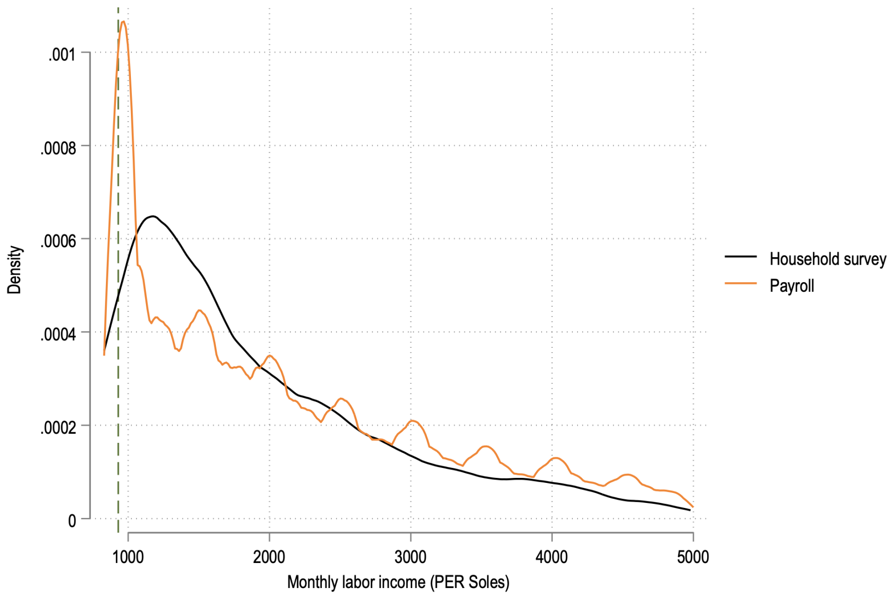
Figure 2: Salary distribution of employees with secondary education, 2021



4. Estimation of PUT

PUT are the unrecorded salaries received by (formally) employed workers beyond what is listed on a firm's payroll. Instead of relying on survey data about PUT, I utilize two datasets that

Figure 3: Salary distribution of employees with higher education, 2021



most governments already collect—administrative payroll and household survey dataset—to do a many-to-one statistical matching approach to estimate PUT. In this section, I explain this process in detail.

Administrative and Survey Datasets The two datasets differ both in what they observe and how wage information is reported. The administrative dataset contains the third-party reported wage, denoted $\bar{w}$, which is not the true wage w. PUT is defined as:

$$\text{PUT} = w - \bar{w}, \quad \text{or equivalently,} \quad w = \text{PUT} + \bar{w}.$$

Since w is not observed in the administrative data, we cannot directly measure true wages. Instead, I rely on the survey dataset, in which individuals self-report their wages. The main assumption is that the self-reported wage $\tilde{w}$ reflects the true wage up to classical measurement error (Assumption 1):

$$\tilde{w} = w + e,$$

where e is a random error with zero mean, independent of w and the covariates X, and with finite variance. Under these assumptions, the self-reported wage is an unbiased estimator of the true wage, and any deviations are purely random. To strengthen the credibility of this assumption, I conduct a sensitivity analysis in later sections, considering how large a systematic bias in self-reported wages would have to be to explain the estimated PUT. If such a bias is implausibly large, this supports the validity of the classical measurement error assumption.

Statistical Matching with Optimal Transport To estimate w for individuals in the administrative dataset, I use statistical matching that aligns the administrative and survey data based on covariates X. These matching variables include schooling, gender, industry, and other characteristics common to both datasets. This approach is grounded in standard matching techniques, where identification relies on the assumption that conditioning on X is sufficient to control for differences between the datasets (Assumption 2)—an assumption similar to the selection-on-observables one used in propensity score matching and other matching methods. This is the Conditional Independence Assumption (CIA).

The goal of the matching is to impute self-reported wages from the survey dataset into the administrative dataset. The key innovation here is to use Optimal Transport (OT) to solve the matching problem. The OT framework matches the two distributions by minimizing the total cost (here, the distance between matched observations) of transporting one distribution (the survey dataset) to another (the administrative dataset). Specifically, I compute a distance between an administrative observation i and a survey observation j using the L^1-norm of their differences in covariates[4]:

$$d_{ij} = \sum_k |X_{i,k} - X_{j,k}|. \tag{1}$$

The optimal transport problem is:

$$\min_G \sum_{i=1}^{n} \sum_{j=1}^{m} G_{ij} d_{ij} \quad \text{subject to} \quad G\mathbf{1} = u, \quad G'\mathbf{1} = v, \quad G_{ij} \geq 0 \tag{2}$$

where $G \in \mathbb{R}^{n \times m}$ is the transport matrix, with G_{ij} the fraction of survey observation j assigned to administrative observation i. u and v are the weight vectors for the administrative and survey datasets, respectively. u is uniform for the administrative data, and v reflects the survey's sampling weights.

Under conditions such as strictly positive marginals and continuity of the cost function, the OT problem has a unique solution G^* (Villani, 2009). This ensures that the survey's distribution is reweighted to match the administrative dataset's distribution, while preserving both distributions' marginals. By maintaining these constraints, OT goes beyond simpler one-sided matching (e.g., nearest-neighbor or propensity score matching) and prevents distortion of the wage distribution. Unlike nearest-neighbor matching, which may fail to preserve the

[4] For categorical variables, I include dummy variables for each category so that their absolute differences contribute to the distance as well.

marginal distributions, OT ensures that the entire distribution of survey wages is represented in the matched sample.

After solving the OT problem, I assign the imputed wage to each administrative record by selecting the survey observation with the highest weight G_{ij}. That is:

$$w_i^* = \tilde{w}_{j(i)}, \quad \text{where} \quad j(i) = \arg\max_j G_{ij}.$$

This step yields a concrete wage imputation that respects the matching structure obtained from OT.

Just to recap, the validity of this method relies on two key assumptions. First, self-reported wages reflect the true wages, subject only to classical measurement error—meaning the error is random, has zero mean, and is independent of the true wage and covariates. Second, the matching variables are sufficient to link the datasets, which corresponds to the Conditional Independence Assumption (CIA): conditional on X, the distribution of self-reported wages in the survey dataset reflects the distribution of self-reported wages for individuals in the administrative dataset.

For now, I proceed under Assumption 1—that the measurement error is classical—and focus on validating the CIA. I revisit the assumption of classical measurement error in the next subsection.

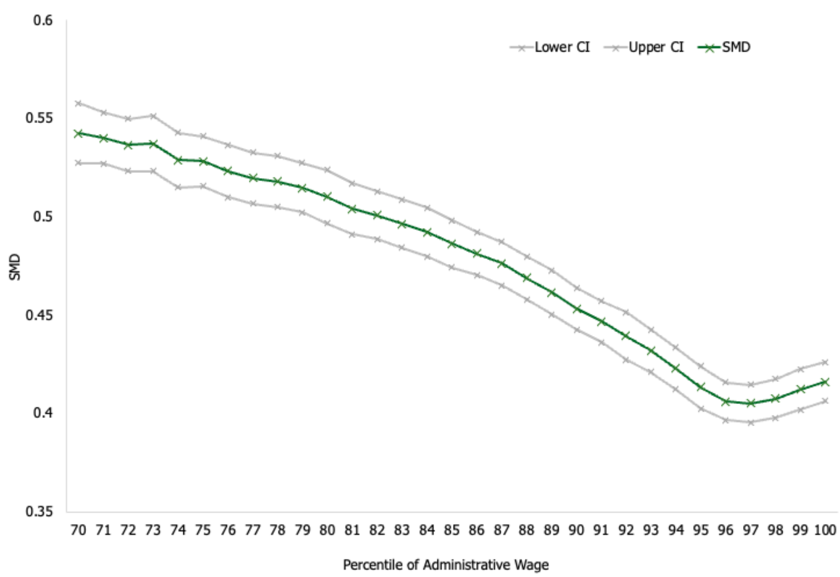
Threshold Selection and CIA Validation. To improve the credibility of the Conditional Independence Assumption (CIA), and given that it is a fact that survey data does not capture well the income of rich people, I identify the wage threshold in the administrative dataset that maximizes comparability with the survey data. The methodology used to identify the optimal threshold is detailed in Appendix MA1, where I validate the approach using synthetic data. Here, I apply the same methodology to the real datasets.

Given the large size of the administrative dataset (approximately 4 million observations), I work with representative samples of the administrative data to make the process computationally efficient. I draw a 1% random sample of the administrative data (approximately 20,000 observations). Then, following the methodology detailed in the Appendix, the administrative 1% sample is iteratively restricted to observations with wages below thresholds corresponding to percentiles of the wage distribution, denoted as p. Specifically, thresholds are tested from the 70th percentile to the 100th percentile, in increments of 1% (resulting in 31 subsets—one for wages below the 70th percentile, another for wages below the 71st percentile, and so on, up to the 100th percentile). These subsets are referred to as the restricted administrative subsets.

For each restricted subset, I apply OT to obtain a matched dataset and then compute standardized mean differences (SMD) in covariates between the administrative and survey datasets. The subset that minimizes the maximum absolute SMD identifies the threshold where CIA likely holds most strongly. To test the robustness of the optimal threshold, I repeat this process for 100 independent 1% samples of the administrative dataset. For each sample, I calculate optimal threshold p_i^* is calculated and then I calculate the standard error to get a measure of its variability.

Figure 4 shows the results from the 100 independent 1% samples, presenting the mean and standard error (SE) of the absolute standardized mean difference (SMD) for different percentiles (thresholds) of the wage distribution in the administrative dataset. The graph suggests that the optimal threshold—the one that minimizes the maximum absolute SMD and thereby maximizes the comparability between the administrative and survey datasets—is approximately the 96th percentile.

Figure 4: SMD for different wage percentiles



After selecting the optimal threshold, I use the full dataset restricted to that threshold to perform the final matching and obtain the PUT estimates. This data-driven threshold selection is a practical approach to strengthening the plausibility of CIA and is in line with best practices for checking matching quality in applied econometric research. Trimming observations where common support is weak (e.g., eliminating units for which there are no close matches) is a well-established method [5]

[5] see Imbens, G. and Rubin, D. (2015), Dehejia, R.H. and Wahba, S. (2002), Heckman et al. (1997).

4.1. Properties of the OT Matching

PUT Estimator The PUT estimator uses the imputed wage $\widehat{w}_i = \sum_{j=1}^{m} G_{ij}\tilde{w}_j$ and the third-party reported wage $\bar{w}_i$:

$$
\begin{aligned}
\widehat{\text{PUT}}_i &= \widehat{w}_i - \bar{w}_i \\
&= \sum_{j=1}^{m} G_{ij}\tilde{w}_j - \bar{w}_i.
\end{aligned}
\tag{3}
$$

Since $\tilde{w}_j = w_j + e_j$, and e_j is classical measurement error (zero mean, independent of w_j and X, and with finite variance), $\widehat{\text{PUT}}_i$ represents a consistent estimator of the true PUT, under the assumptions discussed above.

Consistency Under the CIA and classical measurement error assumptions, the PUT estimator is consistent:

$$\widehat{\text{PUT}}_i \xrightarrow{p} \text{PUT}_i \quad \text{as } n, m \to \infty.$$

The consistency argument follows standard econometric reasoning: Gunsilius and Xi (2023) show that the OT solution G converges to a limit G^*, and since $\tilde{w}_j = w_j + e_j$ with zero-mean error, large-sample averaging ensures $\widehat{w}_i \xrightarrow{p} w_i$. This mirrors the logic behind classical matching and imputation methods, where large samples and unbiased noise ensure consistent estimates. Thus, the OT-based estimator is well-grounded in standard econometric principles of convergence and identification.

The consistency of the PUT estimator relies on the assumption that measurement error is classical. If this assumption is violated—such as in cases where self-reported wages systematically understate or overstate true wages, or where measurement error is correlated with covariates—the transported measurement error term $\sum_{j=1}^{m} G_{ij}e_j$ may introduce bias into the estimator. To address this concern, I will perform robustness checks in Subsection 4.3, exploring scenarios with systematic biases and bounded-error structures. These checks assess the sensitivity of the PUT estimates to deviations from the classical measurement error assumption, ensuring that the results remain valid under plausible alternative error structures.

Efficiency OT is designed to minimize the global cost of matching distributions, and under mild conditions, it is asymptotically efficient relative to less structured matching procedures such as nearest-neighbor matching, propensity score matching, or regression-based imputation methods. These more traditional methods may not preserve the joint distributions as effec-

In these references, the common practice includes using data-driven thresholds or trimming rules (such as discarding treated units whose propensity scores lie outside the range of the control units' scores) to ensure better comparability and improve confidence in CIA.

tively, potentially leading to higher asymptotic variances under the same conditions (Gunsilius and Xi, 2023). For the PUT estimator, efficiency implies lower asymptotic variance when the CIA and classical measurement error assumptions hold. Specifically:

$$\mathrm{Var}(\widehat{\text{PUT}}_i) = \mathrm{Var}(w_i) + \sigma_e^2 \sum_{j=1}^{m} G_{ij}^2,$$

where $\mathrm{Var}(w_i)$ represents the inherent variability in the underlying population from which the individual i is drawn, and σ_e^2 is the variance of the measurement error. The term $\sum_{j=1}^{m} G_{ij}^2$ measures how concentrated the weight distribution is. A more balanced G-distribution reduces the variance contribution of σ_e^2, reflecting standard econometric intuition: spreading risk (or noise) across many observations attenuates variance, just as more dispersed matching reduces the influence of a single noisy match.

4.2. Results

Figure 5 presents the PUT estimates as a share of wages across different levels of third-party reported wages from the administrative dataset. To compute the standard error of the PUT estimator $\hat{\text{PUT}}$, I use a bootstrap procedure by resampling the survey dataset 100 times. For each iteration, I reapply the Optimal Transport (OT) method and calculate the transported (attributed) wages for each individual in the payroll.

The average predicted PUT is 90 Peruvian Soles, which corresponds to approximately 10% of the minimum wage. Figure 5 also shows how PUT varies by third-party reported wage levels. The results indicate a clear negative relationship: as reported wages increase, PUT estimates decline. This pattern is expected. Workers reporting higher wages are less likely to underreport, while those with reported wages close to the minimum wage—represented by the initial value on the graph—are more likely to underreport wages. This suggests that PUT is concentrated among workers whose reported wages are at or near the minimum threshold, where the incentives for cooperation between employers and employees to evade taxes are strongest. It is important to note that the attributed value of PUT for individual that report higher incomes is negative. This potentially suggests that high-income individuals are systematically underreporting their wages in the household survey. However, as shown in Figure

Figure 5: PUT as a share of third-party reported wage (Admin data)

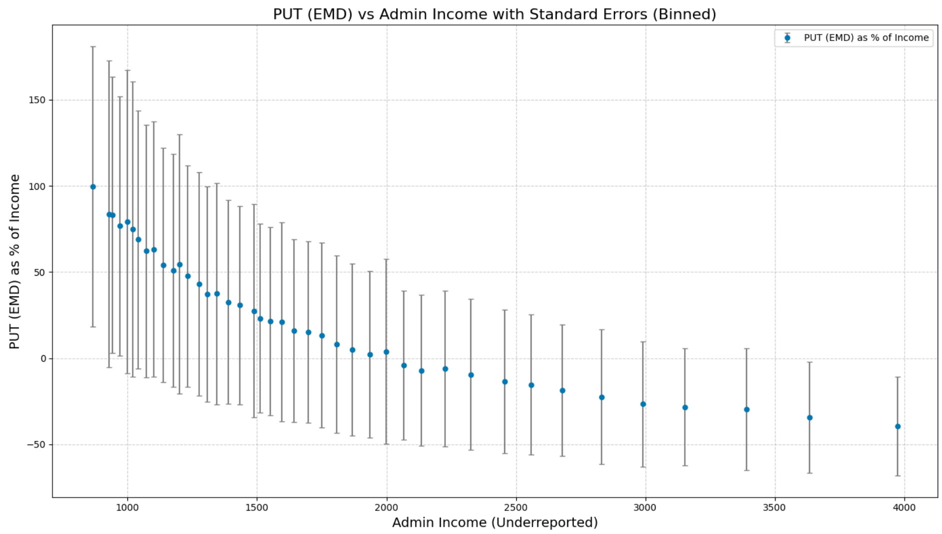
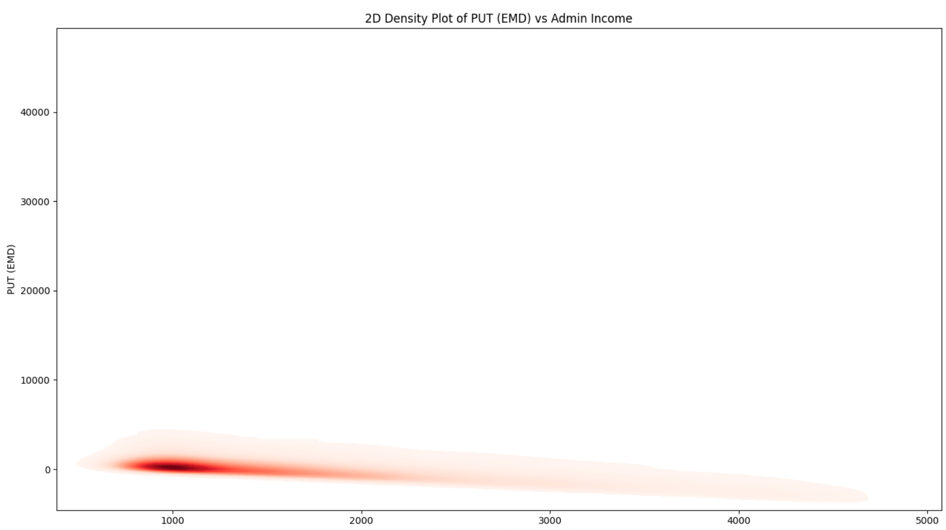


Figure 6: Density of PUT



5. A Simple Model of PUT

5.1. No Firms

This section presents an economy with two types of workers (high- and low-skilled), and a government that sets a linear tax for wages above a threshold w^*. Workers may receive wages fully on the books (fully formal arrangement) or partially under the table (PUT arrangement).

Workers There are L workers: L^H high-skilled and L^L low-skilled, with $L^H + L^L = L$. Wages above threshold w^* are subject to a linear income tax τ. Workers earning wages below w^* are not subject to income tax.

Each worker i has a (dollar-value) benefit v_i from being a fully formal (FF) employee. The distribution of v is given by $F(v)$ with pdf $f(v)$. A higher v means the worker places greater value on being fully compliant rather than receiving part of their wage under the table (PUT). This distribution of valuation for formality is the same for high and low skilled workers.

A worker is fully formal (FF) if their third-party reported wage $\bar{w}$ is equal to their true wage w. The difference between true wage and reported wage is defined as the payment under the table, $\text{PUT} = w - \bar{w}$.

Workers have preferences over consumption c, labor supply l and formality v:

$$u = U(c, l) + 1_{\text{PUT}=0}\{v\}. \tag{4}$$

1_{FF} is an indicator function that equals 1 if the worker is fully formal, or in other words if PUT is zero. The term v only enters utility if the worker is formal. The derivatives of U with respect to c and l are $U_c' > 0$, $U_l' < 0$, and $U_{cc}'' \leq 0$.

Consumption depends on the wage and work arrangement. If workers are under the fully formal arrangement (FF), their consumption is:

$$c = w\,l - \tau\,(w - w^*)\,l + T \tag{5}$$

where w^* is the threshold under which no tax is paid, T is the transfer, and l is labor supply. Workers that are under the PUT arrangement have the following consumption:

$$c = w\,l - \tau\,(w - \underbrace{\text{PUT}}_{w-\bar{w}} - w^*)\,l + T \tag{6}$$

where as before PUT$= w - \bar{w}$. FF workers pay income tax on all earnings above w^*, while PUT workers pay income tax only on the on third-party reported wages $\bar{w}$ that are above above the threshold w^*.

To choose their preferred arrangement, workers choose $\{l^*_{\text{FF}}, l^*_{\text{PUT}}\}$ that maximizes their utility for each case. Then, they decide the arrangement that gives them the higher indirect utility. Thus, conditional on being FF, the FOC is:

$$U_c'\big(c^*_{\text{FF}}, l^*_{\text{FF}}\big)\,[\,w - \tau\,(w - \bar{w})\,] = -\,U_l'\big(c^*_{\text{FF}}, l^*_{\text{FF}}\big). \tag{7}$$

If PUT,

$$U_c'\big(c_{\text{PUT}}, l^*_{\text{PUT}}\big)\,\cdot w = -\,U_l'\big(c_{\text{PUT}}, l^*_{\text{PUT}}\big). \tag{8}$$

Then, the worker picks FF if $V_{\text{FF}} \geq V_{\text{PUT}}$, or PUT otherwise. Specifically,

$$\underbrace{U\big(w\, l^*_{\text{PUT}} + T,\, l^*_{\text{PUT}}\big)}_{U^*_{\text{PUT}}} \;\geq\; \underbrace{U\big(w\, l^*_{\text{FF}} - \tau\,(w - \bar{w})\, l^*_{\text{FF}}, l^*_{\text{FF}}\big)}_{U^*_{\text{FF}}} + v. \tag{9}$$

Define $v^* = U^*_{\text{PUT}} - U^*_{\text{FF}}$. High-skilled workers with $v \leq v^*$ choose PUT; those with $v > v^*$ choose FF.

For now, I assume that all low-skilled workers are employed in the FF arrangement. This is primarily because they will have no incentive to be paid under the table, as they will not subject to the income tax by assumption. In other words, w^* will always be greater than or equal to the low-skilled wage. Consequently, low-skilled workers choose l_L to maximize $U(c, l)$ in the formal market. The first-order condition is:

$$U'_c\big(c^*, l^*_L\big) \cdot w = -U'_l\big(c, l^*_L\big) \tag{10}$$

Note that wages need not be the same for FF and PUT workers of the same skill level. We would expect the PUT wage, w^{PUT}, to exceed $(w^{\text{FF}} - \tau\,(w^{\text{FF}} - w^*))$, in order to compensate for the absence of the utility benefit, v, associated with being formal.

Therefore, the supply of PUT and FF high-skilled workers is:

$$L^S_{\text{PUT}} = L^H\, F(v^*), \quad L^S_{\text{FF}} = L^H\,[1 - F(v^*)]. \tag{11}$$

All low-skilled workers supply l^*_L formally:

$$L^S_L = L^L. \tag{12}$$

Since there are no firms in this section, all who want PUT or FF get it:

$$L_{\text{PUT}} = L^S_{\text{PUT}}, \quad L_{\text{FF}} = L^S_{\text{FF}} \tag{13}$$

Social Planner The planner chooses the linear tax τ, which will be paid by all workers earning wages above w^*, to maximize a generalized utilitarian social welfare function (SWF), subject to the budget constraint. By assumption, w^* will always be larger than or equal to the low-skilled wage. The planner does not intend to tax low-skilled workers.

$$\begin{aligned} \text{SWF} =& L^H\Big[F(v^*)\, U^*_{\text{PUT}} + \int_{v^*}^{B} \big(U^*_{\text{FF}} + v\big)\, dF(v)\Big] \\ &+ L^L \int_0^B \big(U^*_{\text{L}} + v\big)\, dF(v) \end{aligned} \tag{14}$$

Tax revenue comes from wages above the threshold w^* earned by high-skilled workers:

$$\tau\,(w - w^*)\,l^*_{\text{FF}}\,[1 - F(v^*)]\,L^H + \tau\,(w^{\text{PUT}} - w^*)\,l^*_{\text{PUT}}\,F(v^*)\,L^H \;=\; T\big[L^H + L^L\big]. \tag{15}$$

Define the average social welfare weights for each group as:

$$g_{\text{PUT}} \;=\; \frac{U'_c(c^*_{\text{PUT}}, l^*_{\text{PUT}})}{\lambda}, \quad g_{\text{FF}} \;=\; \frac{1}{L_{\text{FF}}\,\lambda}\int_{v^*}^{B} U'_c(c^*_{\text{FF}}, l^*_{\text{FF}})\,dF(v),$$

$$g_L \;=\; \frac{1}{L^L\,\lambda}\int_0^B U'_c(c^*_{\text{L}}, l^*_{\text{L}})\,dF(v)$$

The government is indifferent between giving one more dollar to a worker and using up g_i dollars of public funds, where i denotes the worker type.

Lagrangian and FOCs

$$\begin{aligned}
\mathcal{L} = L^H\,F(v^*)\,U\big(wl^*_{\text{PUT}} - \tau(w - {\scriptstyle\text{PUT}} - w^*)l^*_{\text{PUT}} + T,\, l^*_{\text{PUT}}\big)& \\
+ L^H \int_{v^*}^{B} \big[U(wl^*_{\text{FF}} - \tau(w - w^*)l^*_{\text{FF}} + T, l^*_{\text{FF}}) + v\big]\,dF(v)& \\
+ L^L \int_0^B \big[U(wl^*_{\text{L}} + T, l^*_L) + v\big]\,dF(v)& \\
+ \lambda\Big[\tau\,(w - w^*)\,l^*_{\text{FF}}\,[1 - F(v^*)]\,L^H + \tau\,(w - {\scriptstyle\text{PUT}} - w^*)\,l^*_{\text{PUT}}\,F(v^*)\,L^H - T\big(L^H + L^L\big)\Big]&.
\end{aligned}$$

Taking derivatives with respect to τ and simplifying (using $v^* = U_{\text{PUT}} - U_{\text{FF}}$, labor FOCs, etc.), we define the elasticities:

$$E_l = \frac{\delta l}{\delta(1-\tau)}\frac{1-\tau}{l}, \quad E_{\text{PUT}} = \frac{\delta{\scriptstyle\text{PUT}}}{\delta(1-\tau)}\frac{1-\tau}{{\scriptstyle\text{PUT}}},$$

and derive the final formula:

$$\tau^* = \frac{\tilde{r}}{\tilde{r} + E_l - \alpha^{\text{PUT}}\frac{\text{PUT}}{\bar{w}}\,\left(b_{\text{PUT}} - g_{\text{PUT}}\right)\,E_{\text{PUT}}}, \tag{16}$$

where $\tilde{r} = \alpha^{\text{F}} b^{\text{F}}(1 - g^{\text{F}}) + \alpha^{\text{PUT}} b^{\text{PUT}}(1 - g^{\text{PUT}})$. For each group, the surplus revenue above the tax threshold is defined as

$$b^{\text{F}} = \frac{w^{\text{F}} - w^*}{w^{\text{F}}} \quad \text{and} \quad b^{\text{PUT}} = \frac{\bar{w} - w^*}{\bar{w}}.$$

The labor shares for each group (as a share of the total high-skilled labor) are defined as

$$\alpha^{\mathrm{F}} = \frac{w^{\mathrm{F}}\, l^{\mathrm{F}}\, L^{\mathrm{F}}}{w^{\mathrm{F}}\, l^{\mathrm{F}}\, L^{\mathrm{F}} + \bar{w}\, l^{\mathrm{PUT}}\, L^{\mathrm{PUT}}} \quad \text{and} \quad \alpha^{\mathrm{PUT}} = 1 - \alpha^{\mathrm{F}}.$$

These labor shares represent each group's total payments (formal or PUT) as a proportion of the total reported income above w^*. In addition, $\alpha^{\mathrm{PUT}} \frac{\mathrm{PUT}}{\bar{w}(1-t)}$ represents the scale of the PUT—i.e., how big PUT is compared to reported wages and how many high-skilled workers are in that sector.

The formula captures the redistribution-efficiency trade-off. It shows that the sufficient statistics that define the optimal tax in the presence of PUT are the elasticity of labor supply and the PUT elasticity. The numerator, $\tilde{r} = \alpha^{\mathrm{F}}\, b^{\mathrm{F}}\, (1 - g^{\mathrm{F}}) + \alpha^{\mathrm{PUT}}\, b^{\mathrm{PUT}}\, (1 - g^{\mathrm{PUT}})$, represents the standard redistributive motive coming from the surplus available for redistribution—that is, the extent to which wages exceed the cutoff w^*. Each surplus is weighted by the relative labor share (α) and how much the government values taxing that group (g). A larger surplus increases the government's desire to impose a higher tax rate to exploit that surplus. Note that if $w^* = 0$, then $b^{\mathrm{F}} = b^{\mathrm{PUT}} = 1$, so the expression for τ^* simplifies to

$$\boxed{\tau^* = \frac{1 - \tilde{g}}{1 - \tilde{g} + E_l - \alpha_{\mathrm{PUT}}\, \frac{\mathrm{PUT}}{\bar{w}}\, (1 - g_{\mathrm{PUT}})\, E_{\mathrm{PUT}}},} \tag{17}$$

where

$$\tilde{g} = \alpha^{\mathrm{F}}\, g^{\mathrm{F}} + \alpha^{\mathrm{PUT}}\, g^{\mathrm{PUT}}$$

is the classical weighted average of the welfare weights of all individuals paying taxes, with weights given by their reported income.

The denominator aggregates all efficiency costs. These include the reduction in labor supply (E_l) and the increase in payments under the table, represented by E_{PUT}. As expected, the higher the response of workers to changes in the net-of-tax rate, the lower the optimal tax. This indicates that a strong reallocation response (a large $|E_{\mathrm{PUT}}|$) increases the overall efficiency cost. In other words, if too much wage is shifted to the PUT channel, then the government loses a larger part of the tax base, which effectively raises the cost of taxing an extra dollar.

Besides the share of labor, the PUT elasticity is weighted by two factors. The first, $(1 - g^{\mathrm{PUT}})$, captures the fact that each dollar of PUT 'lost' to tax or distortions is not a full dollar loss from the planner's perspective: the cost is only $(1 - g_{\mathrm{PUT}})$. The larger g_{PUT} is (the more the planner values these particular workers' utility), the smaller is $(1 - g_{\mathrm{PUT}})$, and hence the smaller the net efficiency cost from that distortionary shift. The second factor, $\frac{\mathrm{PUT}}{\bar{w}}$, is a scale factor. It measures tow large PUT payouts are, relative to total reported income above w^*. Intuitively, if large numbers of well-off individuals are receiving big under-the-table payments, then $\frac{\text{PUT}}{\bar{w}}$ is large. Taxing in this zone then faces a significant extra distortion, thus the optimal tax is lower. Note that α_{PUT} also reflects the 'regressiveness' of PUT. If richer workers disproportionately receive PUT payments, then $\frac{\text{PUT}}{\bar{w}}$ increases.

If there are no PUT payments in the economy, $\frac{\text{PUT}}{\bar{w}}$ becomes zero, and the formula reduces to the optimal top income tax formula. Similarly, if PUT workers already report all taxable wages under the table, E_{PUT} becomes zero since there is no margin for adjusting PUT payments when the tax changes. Then the formula collapses to the well-known Saez-Mirrlees top income tax formula:

$$\alpha_{\text{PUT}}(1 - g_{\text{PUT}}) \frac{\text{PUT}}{\bar{w}} E_{\text{PUT}} = 0 \quad \Longrightarrow \quad \tau^* = \frac{1 - \tilde{g}}{1 - \tilde{g} + E_l}. \tag{18}$$

5.2. Introducing Firms

The previous subsection assumed an economy without firms, implying that equilibrium wages do not adjust when the tax rate changes—the only response comes from the labor supply. However, what distinguishes payments under the table (PUT) from classical underreporting or evasion is that the PUT wage is third-party reported by the firm. This requires an arrangement between the firm and the worker that jointly determines the true wage and its split into a reported component and an under-the-table component. In other words, the wage must satisfy

$$w = \bar{w} + \text{PUT}.$$

In this subsection, I extend the model to include firms so as to examine how these responses influence the optimal income tax within the same setting as before. In doing so, I assume that high-skilled labor supply is fixed so that the 'pure' fully formal wage, w^{FF}, is determined in a first-stage equilibrium, while in a second stage firms and workers jointly determine the gross wage for PUT workers, w^{PUT}, which must satisfy

$$(1 - \tau) w^{\text{FF}} \leq w^{\text{PUT}} \leq w^{\text{FF}}.$$

That is, the negotiated w^{PUT} lies between the net-of-tax wage and the fully formal wage. Once w^{PUT} is set, it is split into a reported component and an under-the-table component:

$$w^{\text{PUT}} = \bar{w} + \text{PUT}.$$

Firms. Assume there is one representative firm operating with an exogenous production function $\psi(l^h, l^l)$, which uses high- and low-skilled labor to produce output. Both PUT and fully formal workers are equally productive. Firms earning positive profits are subject to a corporate tax t. Thus, after-tax firm profits are given by

$$\pi = (1-t)\Big[\psi(l^h, l^l) - w^{\text{PUT}}\, l^{\text{PUT}} - w^{\text{FF}}\, l^{\text{FF}} - w^L\, l^L\Big] - t\Big(w^{\text{PUT}} - \bar{w}\Big) l^{\text{PUT}},$$

with

$$l^h = l^{\text{PUT}} + l^{\text{FF}}.$$

The extra term, $-t(w^{\text{PUT}} - \bar{w})l^{\text{PUT}}$, represents the foregone deduction on the corporate tax due to underreporting—since the firm can only deduct the reported wage $\bar{w}$. Thus, a tax wedge arises from the difference $w^{\text{PUT}} - \bar{w}$.

The representative firm maximizes profits by choosing labor inputs:

$$\max_{l^{\text{PUT}}, l^{\text{FF}}, l^L} \left\{ (1-t)\Big[\psi(l^h, l^l) - w^{\text{PUT}}\, l^{\text{PUT}} - w^{\text{FF}}\, l^{\text{FF}} - w^L\, l^L\Big] - t\Big(w^{\text{PUT}} - \bar{w}\Big) l^{\text{PUT}} \right\}. \tag{19}$$

Taking the derivative with respect to l^{PUT} yields the first-order condition (FOC) for PUT workers:

$$\frac{\partial \pi}{\partial l^{\text{PUT}}} = (1-t)\frac{\partial \psi}{\partial l^{\text{PUT}}} - (1-t)w^{\text{PUT}} - t\Big(w^{\text{PUT}} - \bar{w}\Big) = 0. \tag{20}$$

Rearranging, we have

$$(1-t)\frac{\partial \psi}{\partial l^{\text{PUT}}} = (1-t)w^{\text{PUT}} + t\Big(w^{\text{PUT}} - \bar{w}\Big), \tag{21}$$

or, equivalently,

$$\text{MPL}^{\text{PUT}} = w^{\text{PUT}} + \frac{t}{1-t}\Big(w^{\text{PUT}} - \bar{w}\Big).$$

Since $w^{\text{PUT}} - \bar{w} = {}_{\text{PUT}}$, this condition reflects the effective cost of hiring a PUT worker, including the tax wedge.

For fully formal (FF) high-skilled workers and for low-skilled workers, the FOCs are standard:

$$\text{MPL}^{\text{FF}} = w^{\text{FF}}, \quad \text{MPL}^L = w^L.$$

These conditions define the labor demand functions $l^{D,\text{FF}}(w^{\text{FF}})$, $l^{D,\text{PUT}}(w^{\text{PUT}}, \bar{w}, t)$, and $l^{D,L}(w^L)$.

Equilibrium. The market equilibrium in the PUT sector is given by

$$L^{S,\text{PUT}}(w^{\text{PUT}}, \bar{w}, \tau; v) = L^{D,\text{PUT}}(w^{\text{PUT}}, \bar{w}, t) \equiv L^*_{\text{PUT}},$$

where L^*_{PUT} represents total employment in the PUT sector. Similarly, equilibrium in the fully formal high-skilled sector is determined by

$$L^{S,\mathrm{FF}}(w^{\mathrm{FF}}, \tau; v) = L^{D,\mathrm{FF}}(w^{\mathrm{FF}}, t) \equiv L^*_{\mathrm{FF}},$$

and equilibrium in the low-skilled sector is given by

$$L^{S,L}(w^L; v) = L^{D,L}(w^L, t) \equiv L^*_L.$$

Because high-skilled labor supply is fixed, w^{FF} is determined in stage one and is unaffected by changes in τ; only w^{PUT} adjusts via the negotiation.

Since both PUT and fully formal workers are equally productive, we impose the equilibrium condition

$$w^{\mathrm{FF}} = w^{\mathrm{PUT}} + \frac{t}{1-t}\Big(w^{\mathrm{PUT}} - \bar{w}\Big).$$

Recalling that $w^{\mathrm{PUT}} = \bar{w} + \mathrm{PUT}$, we can rewrite this as

$$w^{\mathrm{FF}} = \bar{w} + \frac{1}{1-t}\,\mathrm{PUT}.$$

Differentiating this identity with respect to $1-\tau$ (holding w^{FF} constant) yields

$$E_{\bar{w}} = -\frac{1}{1-t}\frac{\mathrm{PUT}}{\bar{w}}\,E_{\mathrm{PUT}}.$$

where $E_{\bar{w}} = \frac{\delta \bar{w}}{\delta(1-\tau)}\frac{1-\tau}{\bar{w}}$. and $E_{\mathrm{PUT}} = \frac{\delta \mathrm{PUT}}{\delta(1-\tau)}\frac{1-\tau}{\mathrm{PUT}}$. . Thus, once we calibrate E_{PUT}, the elasticity of the reported wage is determined by this relationship. In practical terms, we only need to estimate E_{PUT} as a sufficient statistic for the wage reallocation in the PUT sector.

Note that this does not imply that a change in τ leaves w^{PUT} unchanged. On the contrary, a change in τ induces an adjustment in both $\bar{w}$ and PUT such that the overall $w^{\mathrm{PUT}} = \bar{w} + \mathrm{PUT}$ shifts. The equilibrium condition merely forces these two components to adjust in a linked manner. Hence, E_{PUT} is sufficient to characterize how the PUT wage responds to tax changes.

Social Planner. As before, the planner chooses the linear income tax τ (applied to all workers earning above w^*) to maximize a generalized utilitarian social welfare function (SWF) subject to the government's budget constraint. The SWF is defined as

$$\mathrm{SWF} = L^H\Big[F(v^*)\,U^*_{\mathrm{PUT}} + \int_{v^*}^{B}\Big(U^*_{\mathrm{FF}} + v\Big)\,dF(v)\Big] + L^L\int_0^B\Big(U^*_L + v\Big)\,dF(v) \tag{22}$$

Tax revenue is collected from wages above the threshold w^* earned by high-skilled workers and from corporate taxes from the firms. The government's budget constraint is

$$\begin{aligned}\text{BC:} \quad & \tau\,(w - w^*)\, l^*_{\text{FF}}\, L^{\text{FF}} + \tau\,(w^{\text{PUT}} - w^*)\, l^*_{\text{PUT}}\, L^{\text{PUT}} \\ & + t\Big[\psi(l^*_{\text{FF}} + l^*_{\text{PUT}}, l^*_L) - w^{\text{FF}}\, l^*_{\text{FF}} - \bar{w}\, l^*_{\text{PUT}} - w^L\, l^*_L\Big] \\ & - T\Big[L^H + L^L\Big] = 0\end{aligned} \tag{23}$$

Because the planner takes as given all endogenous responses from households and firms except for the explicit dependence on τ in the revenue side, we can write the total derivative of $\mathcal{L}$ with respect to τ as

$$\frac{d\mathcal{L}}{d\tau} = \frac{\partial \text{SWF}}{\partial \tau} + \lambda\,\frac{\text{BC}}{d\tau} = 0 \tag{24}$$

After taking derivatives with respect to τ and simplifying (using $v^* = U_{\text{PUT}} - U_{\text{FF}}$, the labor FOCs, and the relationship between the $E_{w^{\text{PUT}}}$ and $E_{\bar{w}}$, and the fact that $E_{w^{\text{FF}}} = 0$.)—the optimal tax formula:

$$\tau^* = \frac{\tilde{r} + \alpha^{\text{PUT}}\frac{\text{PUT}}{\bar{w}}\left[\left(g^{\text{PUT}} - \frac{t - g^{\text{PUT}}}{1-t}\right)E_{\text{PUT}} - \frac{t}{1-t}E_l\right]}{\tilde{r} + E_l - \alpha^{\text{PUT}}\frac{\text{PUT}}{\bar{w}}\frac{b - g^{\text{PUT}}}{1-t}E_{\text{PUT}}} \tag{25}$$

where $\tilde{r} = \alpha^{\text{F}} b^{\text{F}}(1 - g^{\text{F}}) + \alpha^{\text{PUT}} b^{\text{PUT}}(1 - g^{\text{PUT}})$. The labor shares α^{F} and α^{PUT} are defined as before, $\alpha^{\text{F}} = \frac{w^{\text{F}}\, l^{\text{FF}}\, L^{\text{F}}}{w^{\text{F}}\, l^{\text{F}}\, L^{\text{F}} + \bar{w}\, l^{\text{PUT}}\, L^{\text{PUT}}}$, $\alpha^{\text{PUT}} = 1 - \alpha^{\text{F}}$). The surplus for each group is also defined as before $b^{\text{F}} = \frac{w^{\text{F}} - w^*}{w^{\text{F}}}$ and $b^{\text{PUT}} = \frac{\bar{w} - w^*}{\bar{w}}$.

As before, this formula captures the trade-off of the marginal net benefit of redistribution against the efficiency cost of increasing the tax rate. Interestingly, even for the case with firms, the sufficient statistics that define the optimal income tax are the typical labor supply elasticity and the PUT elasticity.

The marginal net benefit has two main components. First, $\tilde{r}$ represents the standard redistributive motive coming from the surplus available for redistribution—that is, the extent to which wages exceed the cutoff w^*. The second term of the numerator is new—it reflects the distortions arising from the reallocation of the wage between reported and PUT wages (i.e., how the reallocation to PUT reduces the planner's net gain). E_{PUT} represents how strongly PUT payments decrease when $1 - \tau$ increases. If E_{PUT} is large, a small tax increase leads to a big shift in wages to PUT, meaning less taxable wage and more foregone deductions in the corporate tax. The government values those workers at g^{PUT} and the firm faces a corporate tax wedge $\frac{t}{1-t}$, thus the presence of high reallocation means the net gain from each extra tax dollar is effectively lower.

When $w^* = 0$, every unit of income is taxable and the inequality measure simplifies (with $b^{\mathrm{FF}} = b^{\mathrm{PUT}} = 1$). Then, the redistributive motive becomes $1 - \tilde{g}$ where $\tilde{g}$ is the weighted weight of the welfare weights of the high-skilled $\alpha^{\mathrm{F}}(1 - g^{\mathrm{F}}) + \alpha^{\mathrm{PUT}}(1 - g^{\mathrm{PUT}})$, and the optimal tax rate is given by

$$\boxed{\tau^* = \frac{1 - \tilde{g} + \alpha^{\mathrm{PUT}} \frac{\mathrm{PUT}}{\bar{w}} \left[\left(g^{\mathrm{PUT}} - \frac{t - g^{\mathrm{PUT}}}{1-t} \right) E_{\mathrm{PUT}} - \frac{t}{1-t} E_l \right]}{1 - \tilde{g} + E_l - \alpha^{\mathrm{PUT}} \frac{\mathrm{PUT}}{\bar{w}} \frac{1 - g^{\mathrm{PUT}}}{1-t} E_{\mathrm{PUT}}}} \tag{26}$$

If besides $w^* = 0$, the government assigns zero weight to high-skilled workers ($\tilde{g} = 0$), we get the following formula:

$$\tau^* = \frac{1 - t\, \alpha^{\mathrm{PUT}} \frac{\mathrm{PUT}}{\bar{w}(1-t)} \Big(E_{\mathrm{PUT}} + E_l \Big)}{1 + E_l - \alpha^{\mathrm{PUT}} \frac{\mathrm{PUT}}{\bar{w}(1-t)} E_{\mathrm{PUT}}}. \tag{27}$$

In this formula, the redistribution distortion coming from the corporate tax is made explicit by the fact that every term in the numerator is multiplied by t, the corporate tax rate. When wages are paid under the table (PUT), firms lose the ability to deduct these wages from their taxable income. In effect, as PUT wages increase, firms incur higher effective tax payments, which boosts government revenue through what I call the revenue-PUT channel. Now, consider the effect of an increase in the net-of-tax rate. This change induces two opposing responses among PUT workers. First, a higher net-of-tax rate increases the after-tax wage, thereby incentivizing PUT workers to supply more labor. This response is captured by the labor supply elasticity and increases total compensation as usual. At the same time, an increase in the net-of-tax rate reduces the incentive to pay wages under the table, leading to a decline in PUT wages. This effect is measured by the negative elasticity E_{PUT}. The reduction in PUT compensation means that firms lose less in terms of non-deductible wage expenses—the loss of deductibility is smaller, which effectively increases the tax base relative to what it would be if wages remained higher in the PUT channel.

If the absolute value of the PUT elasticity is larger than the labor supply elasticity, the wage reallocation effect dominates. In that case, the reduction in PUT wages more than offsets the increase in labor supply, resulting in a net positive revenue effect—each additional dollar of tax raises government revenue by more than one dollar. Conversely, if the labor supply elasticity dominates, the efficiency loss from reduced labor supply may outweigh the benefits of decreased non-deductibility. Finally, if we completely mute the corporate tax channel by setting , the distortion from firms' inability to deduct the full wage is eliminated, yielding the same equation as in the case without firms:

$$\tau^* = \frac{1}{1 + E_l - \alpha^{\mathrm{PUT}} \frac{\mathrm{PUT}}{\bar{w}} E_{\mathrm{PUT}}}. \tag{28}$$

6. Simulation & Estimation of PUT Elasticity

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Tables and Figures Appendix

Methodology Appendix

MA1: Simulation and Methodology Validation with Synthetic Data

To validate the methodology for estimating Payments Under the Table (PUT), I use synthetic data to simulate administrative and survey datasets. This controlled environment allows me to assess the performance of the optimal transport (OT) method and compare it to ordinary least squares (OLS) regression under varying sampling strategies.

Synthetic Data Generation The synthetic data comprises two components: an *administrative dataset* and multiple *survey datasets*, each designed to reflect different sampling strategies.

The administrative dataset consists of $n_{\text{admin}} = 2000$ individuals and includes the following variables:

- True Income (w): True incomes are drawn from a truncated normal distribution with a mean of 2000, a standard deviation of 500, and a minimum wage of 1000. This distribution represents the actual income distribution in the economy.
- Underreported Income ($\bar{w}$): A subset of individuals (40%) underreport their incomes to the minimum wage, simulating real-world wage underreporting behavior.
- Covariates (X): Covariates include gender (binary), schooling (primary, secondary, higher), and age group (young, middle-aged, senior), generated to approximate realistic demographic distributions.

The administrative dataset provides both the true incomes (w) and underreported incomes ($\bar{w}$), enabling the calculation of the true PUT ($\text{PUT}_i^{\text{True}} = w_i - \bar{w}_i$) for validation purposes.

Survey datasets are sampled from the *true income distribution* (w) of the administrative dataset. Each survey simulates a different sampling strategy by selecting individuals below specific percentiles of the true income distribution. The surveys are defined as follows:

- Survey 1: Individuals with incomes in p_0-p_{100} (full population).
- Survey 2: Individuals with incomes in p_0-p_{80}.
- Survey 3: Individuals with incomes in p_0-p_{85}.
- Survey 4: Individuals with incomes in p_0-p_{90}.
- Survey 5: Individuals with incomes in p_0-p_{95}.

Each survey includes 200 randomly sampled individuals from the respective percentile range, ensuring representativeness across covariates. These survey datasets serve as inputs for both the OT and OLS methods, enabling direct comparisons under varying sampling assumptions.

Conditional Independence and Threshold Selection The Conditional Independence Assumption (CIA) requires that, conditional on the covariates (X), the distribution of survey incomes ($\tilde{w}$) reflects the distribution of true incomes (w) for individuals in the administrative dataset. To ensure that CIA holds, I iteratively test multiple thresholds for restricting the administrative dataset based on the underreported income distribution ($\bar{w}$).

For each threshold p, I define a subset of the administrative dataset ($\mathcal{A}_p$) as:

$$T_p = \text{Quantile}_p(\bar{w}), \quad \mathcal{A}_p = \{i : \bar{w}_i \leq T_p\}.$$

For each subset ($\mathcal{A}_p$), I calculate the standardized mean differences (SMDs) for the covariates (X) to measure the similarity between the administrative subset and the survey dataset. The SMD for a covariate k is calculated as:

$$\text{SMD}_k = \frac{\mu_{\mathcal{A}_p,k} - \mu_{\mathcal{S},k}}{\sqrt{\frac{\sigma^2_{\mathcal{A}_p,k} + \sigma^2_{\mathcal{S},k}}{2}}},$$

where μ and σ^2 are the mean and variance of covariate k in the administrative subset ($\mathcal{A}_p$) and the survey dataset ($\mathcal{S}$). The optimal threshold p^* minimizes the maximum absolute SMD across all covariates:

$$p^* = \arg\min_p \max_k |\text{SMD}_k|.$$

The optimal threshold identifies the administrative subset ($\mathcal{A}_{p^*}$) most comparable to the survey dataset.

Statistical Matching with Optimal Transport Using the administrative subset defined by the optimal threshold ($\mathcal{A}_{p^*}$), I perform statistical matching with the survey dataset using OT. The OT method aligns the distributions of the two datasets while preserving their marginal distributions. For each administrative record, OT imputes a self-reported wage (w^*) from the survey dataset, and the PUT is calculated as:

$$\text{PUT}_i^{\text{OT}} = w_i^* - \bar{w}_i.$$

OLS Estimates To compare OT with OLS, I fit an OLS regression model for each survey dataset. The model estimates the relationship between self-reported wages ($\tilde{w}$) and the covariates (X):

$$\tilde{w}_i = \beta_0 + \sum_k \beta_k X_{i,k} + \epsilon_i.$$

Using the estimated coefficients ($\hat{\beta}_k$), I predict self-reported wages (w^{OLS}) for all individuals in the administrative dataset:

$$w_i^{\text{OLS}} = \hat{\beta}_0 + \sum_k \hat{\beta}_k X_{i,k}.$$

The OLS-based PUT estimate is then calculated as:

$$\text{PUT}_i^{\text{OLS}} = w_i^{\text{OLS}} - \bar{w}_i.$$

This process is repeated for each survey dataset, yielding multiple sets of OLS-based PUT estimates.

Results and Comparison The following table summarizes the key statistics for OT and OLS across all survey datasets:

	Optimal Transport			OLS			True PUT
	Mean PUT	SE PUT	N	Mean OLS	SE OLS	N	
Survey1	400.33	17.37	1966	340.33	14.06	2000	414.52
Survey2	506.04	15.48	1606	319.12	14.07	2000	507.44
Survey3	406.55	16.63	1926	352.11	14.11	2000	423.13
Survey4	413.38	16.54	1920	338.32	14.04	2000	424.46
Survey5	394.99	17.47	1966	362.04	14.10	2000	414.52

Table MA1: Summary Statistics of PUT Estimates from OT and OLS

The following figure compares the mean PUT estimates from OT, OLS, and the true PUT across all survey datasets. Error bars indicate the standard errors for OT and OLS estimates:

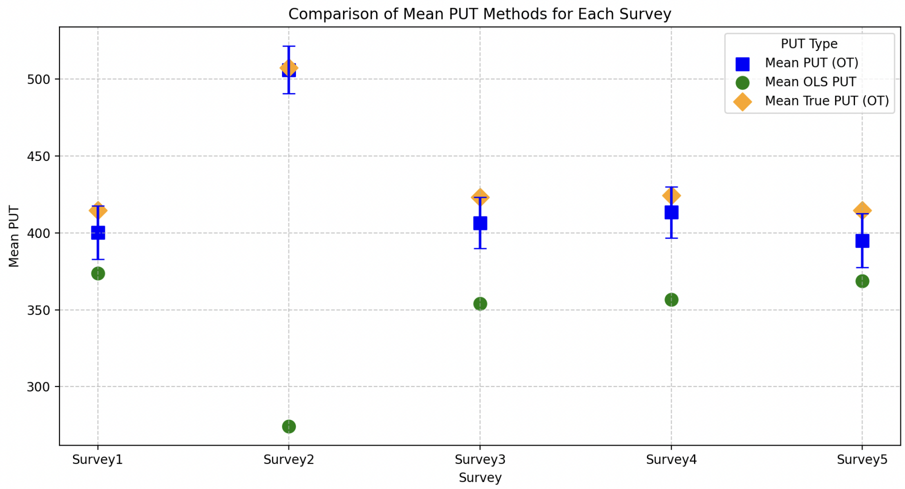

Figure A1: Comparison of Mean PUT Methods for Each Survey

This table and figure demonstrate the robustness of the OT method in reconstructing PUT estimates under various survey sampling strategies. These results provide a methodological foundation for applying the OT method to real-world administrative and survey datasets.

MA2: Alternative Estimation of PUT using OLS

Methods An alternative method of estimating PUT is through OLS and predicting the (assumed) actual salary of the employees in the payroll data using the firm characteristics and the socioeconomic characteristics of the employees present in both the survey and the payroll. To do this, I estimate the following linear regression in the survey:

$$y_i = \sum_k \beta_k sch_{ik} + \sum_j \beta_j ind_{ij} + \theta \text{Lima}_i + \gamma' X_i + \epsilon_i \tag{29}$$

where y_i is the monthly income of employee i, sch_{ik} takes the value of one if the employee i has an educational attainment k and zero otherwise, ind_{ij} takes the value of one if the employee i works in a firm of industry j and zero otherwise, Lima_i takes the value of one if the employee i works in Lima (the capital) and zero otherwise. X_i includes age and gender.

Then, using the parameters ($\hat{\beta}$, $\hat{\theta}$, $\hat{\gamma}$) from regression (1) and the socioeconomic characteristics of workers in the payroll, I predict the true salary of workers in the payroll dataset. The difference between the predicted total salary and the observed salary are assumed to be the PUT.

Results First I estimate the parameters of equation (12) in the household survey ENAHO by OLS for each year. Table 1 shows the results for 2021. Estimators show the correlation between each variable and monthly wages. As expected, the higher the education level, the higher the monthly salary. The premium for having a bachelor's degree is around 700 Peruvian soles or \$200 and the premium for a master's degree is around \$1,000. For reference, the minimum wage is around \$300. For age, the estimators are an inverted U shape. Mining and construction are the industries in which the salary is higher. Finally, being male and living in Lima are also correlated with higher monthly wages.

Then, using the estimators from Table MA1, I predict the monthly salaries for the employees in the payroll. Table MA2 compares these predictions with the observed values for 2021. The first observation is that the predicted wage is higher than the reported wage for all education levels. I assume that this (statistically significant) difference are the PUT. Second, the higher the education level, the larger the difference between predicted and reported salaries. For those with secondary studies, the difference is 2-3%, while for those with master's degrees it is 150%. This is because on average and for each group the reported salary is not higher than 1.5 times the minimum wage. Thus the higher the salary, the larger the estimated PUT.

Table MA2: OLS Estimates in Household Survey ENAHO, 2021

	Monthly income (PER soles)
	2021
	(1)
Education: Secondary	79.714**
	(37.595)
Education: Bachelor's	720.374***
	(41.015)
Education: Master's or Higher	3,293.643***
	(90.268)
Age Group: 25-29	93.674**
	(44.802)
Age Group: 30-44	282.292***
	(38.979)
Age Group: 45-60	389.813***
	(42.805)
Age Group: 65+	231.421***
	(67.560)
Industry: Mining	783.622***
	(79.592)
Industry: Manufacture	38.840
	(49.208)
Industry: Construction	321.774***
	(51.980)
Industry: Commerce	-125.358**
	(50.256)
Industry: Services	-14.650
	(45.553)
Male	294.938***
	(26.904)
Private Pension	186.979***
	(27.408)
Firm is Small	-223.799***
	(34.389)
Lima	239.056***
	(27.025)
No. Observations	7,305
R^2	0.275

Note: OLS estimates from equation (1) in the household survey ENAHO. Omitted education is 'Less than Secondary', omitted industry is 'Agriculture', omitted age group is 15-24 years old. Standard errors in parentheses. * $p \leq 0.10$, ** $p \leq 0.05$, *** $p \leq 0.01$.

Table MA3: Average observed and predicted income in payroll, 2021

	Monthly income (PER soles)		
	2021		
	Observed (1)	Predicted (2)	Difference (2)-(1)
Education level:			
Less than Secondary	1,081.92	1,167.56	85.63***
Secondary	1,221.52	1,248.39	26.87***
Bachelor's	1,690.87	1,901.59	210.71***
Master's or Higher	1,791.51	4,587.57	2796.05***
No. Observations	5,035,724	5,035,724	

Note: Predicted and observed monthly income in the payroll dataset. * p≤ 0.10, ** p≤ 0.05, *** p≤ 0.01: Statistically different from 0 in the test for difference of means.