

Payments Under the Table: Estimation and Optimal Tax Policy

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Abstract

This paper studies how firm–worker agreements to underreport wages affect tax policy design. In most tax systems, firms act as third-party reporters to limit evasion, but this mechanism weakens when employers pay part of workers’ wages off the books—what I refer to here as payments under the table (PUT). I develop a model of optimal labor income tax rates in which PUT arise endogenously from firm–worker interactions, and a corporate tax is also in place. The model shows that the corporate tax modifies the standard formula for the optimal labor income tax rate through two channels: (i) a fiscal externality, as PUT cannot be deducted from firms’ taxable profits and thus raise corporate tax revenue; and (ii) a behavioral response, as higher corporate tax rates reduce firms’ incentives to pay under the table and narrow the scope for workers to evade, thereby lowering the elasticity of taxable income (ETI). Together, these effects imply that the optimal labor income tax rate increases with the corporate tax rate. Empirically, I compare administrative payroll records with household surveys in Peru. Because the two sources cannot be linked, I use optimal transport to compute the smallest amount of PUT consistent with both wage distributions. I find that at least 13.2% of private formal employees receive PUT, and those who do are paid at least 9.7% of their reported wage under the table. Exploiting two reforms to Peru’s Agricultural Regime, I show that the ETI is large when only the labor income tax rate rises and much smaller when the labor income and corporate tax rates rise together, consistent with the model’s predictions.

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1. Introduction

Governments use income taxes to redistribute resources from richer to poorer individuals, with the goal of promoting greater equity (Mirrlees, 1971; Diamond and Saez, 2011). But taxes change behavior. People may work less when taxes increase (real responses) or try to reduce their reported income without changing their actual work effort (avoidance or evasion responses) (Saez, 2001; Kleven et al., 2011). To limit evasion, governments often rely on firms to act as third-party reporters. By requiring employers to report workers’ earnings, tax authorities can use firms’ information and administrative capacity to improve compliance (Kleven et al., 2016). However, the effectiveness of third-party reporting depends on firms’ truthful reporting of wages. When employers and workers agree to underreport earnings, the informational role of firms as tax collectors is undermined (Slemrod, 2008). This problem is particularly relevant in countries with limited enforcement capacity and large informal sectors.

A growing body of evidence from low- and middle-income countries shows that many employees receive a higher wage than the one officially reported by their *employer*. The official wage is the amount declared by firms to tax and social security authorities, while the difference—paid off the books, often in cash—is referred to as an envelope wage or payment under the table (PUT). These workers are registered on a firm’s payroll, which is why part of their wage is reported. They are not workers hired entirely outside the formal system, who are typically referred to as ‘informal workers’ in the labor economics literature. Instead, PUT represent a hybrid form of employment: the job itself is formally registered, but compensation is only partially declared. In this sense, PUT can be understood as a partial informality.

The existing evidence on PUT has primarily focused on measurement, as evasion is inherently difficult to observe directly. The literature has relied either on surveys that ask workers directly whether they receive payments under the table from their employers in addition to their reported wages (Williams and Padmore, 2013; Feinmann et al., 2025b), or on inferring PUT indirectly by exploiting policy or enforcement changes that affect reported but not true wages (Bergolo and Cruces, 2014; Kumler et al., 2020; Gavaille and Zasova, 2023). Despite this growing empirical evidence, the implications of PUT for tax policy remain largely unexplored.

This paper makes two contributions. First, it measures PUT from data that most governments already collect—administrative payroll records and household surveys—without linking them and without assuming who in one source corresponds to whom in the other. Second, it incorporates PUT into a model of optimal labor income taxation in an economy with a corporate tax, to study how tax policy should adapt when evasion takes this form.

In the standard framework, the optimal income tax balances the gains from collecting more taxes—more revenue to transfer to poorer individuals (more redistribution)—against the efficiency costs of taxation, captured by how reported income responds when tax rates increase, either because people work less or evade more. This responsiveness is summarized by the elasticity of taxable income (ETI). I show that this familiar trade-off continues to hold even when PUT are widespread. The novelty lies in the role of the corporate tax. Because PUT cannot be deducted from firms’ taxable profits, a higher corporate tax generates a positive fiscal externality that raises revenue and increases the redistribution benefits of taxation. At the same time, a higher corporate tax reduces firms’ incentives to pay under the table, which limits workers’ ability to evade and therefore lowers their response to tax changes — that is, it reduces the ETI. Both mechanisms strengthen the case for a higher optimal income tax compared to settings where evasion is purely a worker decision and firms play no role. I test

these predictions using Peruvian data and a reform that simultaneously changed both income and corporate tax rates, and I find empirical responses consistent with the model.

Getting this main result involves three steps, which form the building blocks of the paper. In the first part, I measure PUT in Peru by comparing two kinds of data: administrative payroll records, which contain the wage each employer reports to the Ministry of Labor and Employment Promotion (MTPE), and two household surveys, which record the wage each worker self-reports to the National Institute of Statistics and Informatics (INEI). Before any comparison, I harmonize the two sources to the same population: formal employees of private employers, in their main job. Within cells of comparable workers—same firm size and sector, reweighted to the same age, sex and region—I then compare the two wage distributions at three points: the mean, the median, and the 30th percentile of self-reported wages. The key assumption is that, within each cell, the self-reported wages of survey respondents follow the same distribution as the true wages of payroll workers, so that any gap between the two distributions is PUT. I find that self-reported wages exceed third-party reported wages by 5.5% at the mean and 8.4% at the median, and that at or below the survey’s 30th percentile the payroll has an excess mass of 7.8 percentage points of workers. At firms with 10 or fewer workers, the gaps are 22.5%, 31.2% and 29.0 points.

The mean, the median and the 30th percentile describe how far apart the two distributions are, but not how PUT is spread across workers: the same gap can come from a few workers receiving large payments or from many workers receiving small ones. Telling the two apart shows whether PUT is a common practice or one confined to a few workers, and the share of workers who receive it is what direct surveys measure when they ask workers whether they are paid under the table.

Separating the share of workers who receive PUT (the extensive margin) from how much they receive (the intensive margin) requires knowing which self-reported wage belongs to which payroll worker. Both sources are anonymized to protect privacy, so they cannot be linked one-to-one. Instead of assuming a pairing (a copula), I consider every joint distribution of reported and self-reported wages consistent with the two observed marginal distributions, and report lower bounds that must hold for all of them. Each bound solves an optimal transport (OT) problem: for the extensive margin, for example, OT finds the pairing with the fewest workers whose self-reported wage exceeds their reported wage. I find that at least 13.2% of private formal employees receive PUT, and that those who do receive on average at least 9.7% of their reported wage under the table.

For any single pairing, the extensive margin times the intensive margin is the average PUT across all workers, including those who receive none.¹ Multiplying the *two bounds*, however, does not give the lower bound on this average, because each bound is attained by a different pairing. Like the bounds on the two margins, the lower bound on this average solves an optimal transport problem, and its solution is the pairing in which workers keep the same rank in both distributions (rank invariance). In the economy as a whole, PUT is on average at least 7.7% of the reported wage.²

In the second part of the paper, I develop a model of the optimal personal income tax in an economy where PUT arise endogenously in labor market equilibrium and where a corporate tax is also in place. Workers’

¹Workers whose self-reported wage falls below their reported wage count as receiving zero.

²These results are consistent with a direct survey that we ran across Latin America in 2024 (Feinmann et al., 2025a). In Peru, 10% of formal employees report receiving PUT, below the lower bound on the extensive margin, consistent with workers understating PUT in surveys, as they do other illegal or socially undesirable behavior (Tourangeau and T Yan, 2007). Those who report receiving it put it at about 28% of their reported wage, above the lower bound on the intensive margin.

personal income is subject to a linear income tax, and firms' profits are taxed under a linear corporate tax.³ PUT matter because they are not subject to personal taxation (a benefit for workers) but are also non-deductible from firms' taxable profits (a cost for firms).

I start by modeling a labor market in which workers choose whether to supply labor under a fully formal arrangement (no PUT) or to accept an arrangement that includes a share of PUT. Workers are identical in productivity but differ in an exogenous informality cost, which can be interpreted as the valuation they place on payroll-linked benefits. Workers self-select into formal or PUT arrangements according to this cost. Firms are indifferent between hiring formal and PUT workers as long as the total cost of hiring is equal across arrangements. The equilibrium wage in each arrangement adjusts to clear the market. Because PUT cannot be deducted from taxable profits, wages in the PUT sector are lower to offset the higher effective cost to firms. Workers in the PUT arrangement therefore receive part of their compensation under the table, while fully formal workers report their entire wage. Given these labor market outcomes, the government chooses the income tax rate (and lump-sum transfer) that maximizes a social welfare function, subject to a balanced-budget constraint and a fixed corporate tax.

Using this model, I derive the conditions that characterize the optimal income tax rate. The solution to the planner's maximization yields an optimal income tax formula aligned with the well-known Mirrlees-Saez framework, balancing the equity-efficiency trade-offs of a change in the income tax rate. The elasticity of taxable income (ETI) remains the key sufficient statistic. The novelty is that the formula now includes two channels through which the corporate tax directly affects the optimal income tax. First, PUT introduce a fiscal externality in the numerator. When wages are paid under the table, personal income tax revenue falls, but the same under-the-table payments increase firms' taxable profits and therefore corporate tax revenue. The government thus recovers part of the lost revenue automatically through the corporate tax base, which lowers the effective revenue cost of underreporting and raises the optimal income tax relative to a setting without this offset. Second, the ETI in the denominator becomes a negative function of the corporate tax. In equilibrium, firms are indifferent between hiring workers formally or under the table, as wages adjust to offset the non-deductibility of PUT payments. A higher corporate tax increases the cost of PUT arrangements, compresses the wage gap between formal and PUT contracts, and reduces the scope for PUT underreporting. As a result, workers' reported income becomes less elastic. Similar to Slemrod and Kopczuk (2002), the ETI is endogenously shaped by worker behavior and firm incentives through the corporate tax. The magnitude of these two channels depends on the ratio of PUT to reported income in the economy, the parameter measured in the first part.

Together, these two channels imply that the optimal income tax rate increases with the corporate tax rate. When the corporate tax is zero, the model collapses to the standard evasion case, where underreporting decisions fall entirely on the worker side, the ETI is higher, and the optimal income tax is lower. As the corporate tax rises, PUT become less attractive for firms, reducing the ETI and strengthening the fiscal externality, both of which raise the optimal income tax. When the corporate tax rate exceeds the personal income tax rate, incentives for PUT disappear, and the model converges to full compliance. These results depend on the non-deductibility of PUT. If firms were able to deduct these payments, the cost of PUT would vanish, returning the model to a case closer to standard evasion, where all incentives lie on the worker side. In practice, anecdotal evidence suggests that firms deduct only part of these payments, placing real economies somewhere between the two extremes

³I assume a single personal income tax that encompasses both the payroll and income tax.

of full and zero deductibility. In this intermediate case, the corporate tax continues to play a central role by shaping both the fiscal externality and the ETI—and, therefore, the optimal income tax rate.

In the final part of the paper, I bring the model to the data using two recent reforms in Peru’s labor tax regimes. I focus on the key theoretical prediction that the elasticity of taxable income (ETI) is a decreasing function of the corporate tax.

The first reform, introduced in 2021, increased the payroll tax for workers employed under the Agricultural Regime (AgR) but left the corporate tax unchanged. The policy applied only to field workers hired under the AgR, who serve as the treated group. In contrast, administrative employees within the same agricultural firms could not be hired under the AgR and had to be employed under the General Regime (GR). These workers, exposed to the same firm- and sector-specific shocks but unaffected by the tax change, form the control group. The second reform, implemented in 2023, simultaneously increased both the payroll and corporate tax rates for large firms under the AgR, while the GR remained unaffected. This differential exposure allows me to examine how changes in corporate taxation affect the responsiveness of reported income to labor taxes.

Using a continuous difference-in-differences design, I estimate the elasticity of reported income with respect to the net-of-tax rate for workers in the AgR. I find large ETIs of around 2 during the first reform, consistent with weaker enforcement and greater scope for underreporting in developing economies. However, the response is attenuated in 2023, when the corporate tax also increased, consistent with the model’s prediction that higher corporate taxation reduces the attractiveness of PUT and lowers the sensitivity of reported income to labor taxation. Because the tax changes differed by firm size, I also estimate the ETI separately for small and large firms, each compared with general-regime workers in firms of the same size. The validity of the ETI estimates relies on the standard parallel-trends assumption. Event-study analyses confirm that pre-trends were parallel and show a discrete decline in reported income following the 2021 payroll tax hike but little response after the 2023 reform. Plugging these estimates into the optimal tax formula, the optimal labor income tax is 26% when the corporate tax is 15% and 44% when it is 20%, against 15% if evasion were a decision of workers alone and 67% if reported wages were taken as true.

Related literature. This article contributes to several strands of literature, the primary one being the analysis of tax evasion and optimal taxation by explicitly incorporating payments under the table (PUT) into the discussion.

The existing literature on PUT or ‘envelope wages’ has primarily focused on documenting and measuring its prevalence. Two main approaches have been used. The first approach relies on survey data, where workers are asked directly whether they receive part of their pay off the books. In Europe, Barth and Ognedal (2018) present survey evidence that around 5% of employees in the European Union receive part of their wages off the books, though this share varies widely—from 15% in Romania and 10% in Bulgaria to 5–7% in Spain (Di Nola et al., 2019). Williams and Padmore (2013) use Eurobarometer data across 28 European countries and similarly find that about 3% of workers report receiving underreported salaries, with much higher prevalence among low-skilled and Eastern European workers. In Latin America, Feinmann et al. (2025b) find that 25% of formal employees in Brazil admit to receiving PUT for about 20% of their wages, with higher-wage workers evading a larger share. In Feinmann et al. (2025a), we extended this survey in 2024 to Argentina, Chile, Colombia, Mexico, and Peru. Across the six countries, about 17% of formal employees receive PUT, for about 23% of their

earnings, with substantial heterogeneity, from about a quarter of employees in Argentina to about 5% in Chile. Across contexts, this literature consistently documents that PUT are widespread.

The second approach infers underreporting indirectly, typically by exploiting reforms that affect reported—but not actual—compensation. In Uruguay, Bergolo and Cruces (2014) show that after a reform reinforcing the link between reported wages and future social security benefits, reported earnings rose while total labor costs remained unchanged—consistent with a reduction in PUT. Kumler et al. (2020) find similar evidence in Mexico following a 1997 pension reform, with the largest increases in reported wages occurring among younger workers and small firms; they also compare administrative and survey wage distributions within cells, the comparison of the first part of my measurement. Bíró et al. (2022) detect comparable responses in Hungary, finding that stronger enforcement reduces bunching at contribution thresholds. Bjørneby et al. (2021) identify underreporting in Norway by comparing employer-reported wages to third-party financial information, while Gavaille and Zasova (2023) document that increased monitoring in Latvia led to higher reported earnings and smaller discrepancies relative to actual pay. Together, these studies provide compelling evidence that the extent of wage underreporting responds systematically to enforcement and contribution incentives.

An exception to these two approaches is López-Luzuriaga et al. (2023), who detect envelope wages in Ecuador by combining electronic invoicing records with payroll tax returns. Their method uses billing data as a quasi-third-party verification device to infer unreported wage components. This is a compelling innovation, but it depends on full coverage of e-invoicing systems—an infrastructure still unavailable in many low-capacity developing countries. By contrast, my approach is designed to work with administrative and household survey data that governments already collect, making it scalable and immediately applicable in such settings.

This literature has largely focused on documenting the existence and magnitude of PUT, without examining how their presence should change the design of tax policy. This paper advances the literature in two main ways. First, it separates how many workers receive PUT from how much they receive using two sources that cannot be linked, and reports bounds that hold under every pairing consistent with the data rather than estimates that depend on an assumed one. This avoids the costs and potential biases of direct survey questions while relying only on data that tax authorities already hold. Second, it goes beyond measurement to study the implications of PUT for tax policy. I develop a theoretical model in which firms and workers jointly determine how much of the wage is reported and derive optimal tax formulas that incorporate this behavioral margin. This is the first paper to link the measurement of PUT to its implications for optimal tax design, bridging two strands of literature—empirical work on wage underreporting and normative analyses of tax policy—that have evolved largely in isolation.

This paper also contributes to the optimal income taxation literature (Mirrlees, 1971; Saez, 2001; Diamond and Saez, 2011), which studies how governments can redistribute income while minimizing efficiency costs. While this literature does allow for tax evasion, it typically models evasion as an individual worker decision and treats third-party reporting by firms as a silver bullet that effectively closes the evasion margin. In other words, once wages are reported by the employer, compliance is assumed to be complete. I depart from this assumption by allowing firms and workers to jointly determine how much of the wage is reported, thereby endogenizing the possibility that third-party enforcement may fail. In doing so, the paper connects the optimal tax tradition to the foundational evasion literature—beginning with Allingham and Sandmo (1972) and Yitzhaki (1974), who model individual non-compliance under audit risk—and to more recent work on third-party reporting and enforcement

capacity (Kleven et al., 2011; Kleven et al., 2016). But whereas these models assume that firm-reported wages are truthful by construction, this paper allows for underreporting even in the presence of employer reporting and shows that the existence of PUT fundamentally alters optimal income and corporate tax design.

Beyond the tax evasion literature, this paper also contributes to the broader work on labor informality, which studies earnings that escape taxation but typically frames informality as a binary firm or sectoral choice. A large empirical literature documents the prevalence, determinants, and consequences of informality (Williams and Padmore, 2013; La Porta and Shleifer, 2014; Ulyssea, 2020), emphasizing its implications for productivity, welfare, and tax capacity. However, informality in this literature is generally modeled as a binary decision—either a job is formal or informal—rather than as a continuous choice over how much income is reported. This paper instead focuses on the intensive margin of informality, studying partial underreporting within formal employment (i.e., PUT), and analyzes how this continuous evasion margin affects optimal tax design.

Finally, this paper contributes to the use of optimal transport (OT) in economics and to partial identification from two unlinked distributions. In labor economics, Kim and Lee (2024) use OT to recover the joint distribution of worker skills and job characteristics from observed matches, and Arellano and Bonhomme (2023) apply an OT-based matching framework to recover the latent distribution of income shocks from panel earnings data. In industrial organization, Li et al. (2019) use inverse OT to back out the implicit matching cost function underlying observed college admissions and labor market allocations. In trade, Gaskin et al. (2024) use OT with neural networks to learn counterfactual trade cost structures from observed global trade flows, while Leite and De Bacco (2024) use an OT-inspired algorithm to reconstruct realistic transportation networks from minimal origin–destination data. When only the two marginal distributions of a joint outcome are observed, the joint is partially identified (Manski, 2003), and the distribution of a difference between the two variables is bounded (Makarov, 1981), as in the treatment-effects literature that bounds the distribution of treatment effects from the two potential-outcome distributions (Heckman et al., 1997; Fan and Park, 2010; Frandsen and Lefgren, 2021). This paper brings the two together: it uses OT to compute sharp bounds on the extensive and intensive margins of underreporting, including the intensive margin, which has no closed form, and it is, to my knowledge, the first to apply these tools to measure wage underreporting.

The rest of the paper is organized as follows. Section 2 describes the institutional setting, focusing on the Peruvian tax system. Section 3 measures payments under the table (PUT) by comparing payroll and survey wage distributions, and bounds the share of workers who receive PUT and how much they receive using optimal transport. Section 4 develops the model of optimal income taxation with PUT. Section 5 estimates the elasticity of taxable income and uses the estimates to compute the optimal labor income tax. Section 6 concludes.

2. Institutional Setting

Payments under the table (PUT) are wage underreporting arrangements that require coordination between firms and workers. This is what differentiates them from classical forms of evasion, where workers misreport income unilaterally. Because PUT depend on joint incentives, they interact with both sides of the tax system: the worker side (personal income and payroll taxes) and the firm side (corporate taxation and deductibility rules). Understanding this institutional structure is essential to analyzing PUT.

Most countries, including Peru, have three main tax instruments relevant for labor earnings: (i) a personal income tax on workers, (ii) payroll taxes that finance social security benefits (borne by workers and/or firms),

and (iii) a corporate income tax on firms' taxable profits. PUT interact with all three. For workers, PUT are not declared to tax or social security authorities, and therefore escape both personal income and payroll taxation. This is the benefit of PUT. For firms, however, these payments cannot be deducted as labor expenses, and thus increase the corporate tax base. This is the cost of PUT.

Before describing the tax system in detail, I first explain why Peru is particularly relevant for analyzing PUT. Peru has one of the most informal labor markets in Latin America: around 70% of workers are employed entirely outside the formal system. Importantly, informality in Peru is not merely the result of exclusion from formal jobs; it is often a deliberate choice. A large body of evidence shows that workers and firms opt out of formality when the perceived benefits of contributing are low, especially given weak enforcement and the limited value many individuals attach to future social security benefits (Yamada, 1996; Loayza, 1996; Perry et al., 2007). Even during periods of strong growth, informality has remained persistent and largely voluntary (Bosch and Maloney, 2010; Levy, 2018). These strong preferences for informality suggest that workers and firms may also have high willingness to engage in PUT arrangements.

Enforcement capacity is limited and biased toward detecting who is registered, not whether reported wages are truthful. As of 2023, Peru had fewer than 800 labor inspectors overseeing nearly 20 million workers (U.S. DOL, 2024; SUNAFIL, 2023). In practice, the tax authority (SUNAT) prioritizes uncovering non-registration or omitted (fully informal) workers (SUNAT, 2023). This institutional setting is conducive to formal-but-underreported employment, the margin this paper studies.

Moreover, household surveys in Peru are a good source for both wages and formality status. Given that informality is a central policy concern, these surveys are the primary instrument to measure labor market conditions (as administrative data do not capture informal workers). The national statistics office (INEI) has invested heavily over decades to ensure truthful reporting: the survey is anonymized, widely trusted, and known by workers to be used for statistical purposes (not enforcement). Administrative payroll declarations, on the other hand, are legal compliance documents. Tax liability is calculated using what is reported there. The survey is therefore the better source for measuring true earnings and formality status, although, like any survey, it carries nonresponse and reporting error, which Section 3 measures, while administrative records reveal what firms actually report. It is precisely this wedge between reported and true wages that I will use to estimate PUT in Section 3.

I now describe the tax and contribution system relevant for firm–worker decisions over wage reporting. The objective is to highlight the institutional features of the Peruvian tax system that incentivize PUT.

Personal Income Taxation and Payroll Taxes Table 1 summarizes income and payroll taxes. On the worker side, labor income is subject to a progressive personal income tax (PIT), withheld monthly by the employer. The tax schedule applies only above a standard deduction of 7 tax units⁴, and marginal rates rise with income from 8%, 14%, 17%, 20% to 30%. Employees must also contribute 13% of earnings to the pension system, either the public pay-as-you-go pension system or the private savings-funded pension system. On the firm side, employers are required to contribute 9% of reported payroll to EsSalud, the national health insurance system, and approximately 9.7% in mandatory severance (CTS), which is an individual savings account for each

⁴There is a unique tax unit per year. Between 2020 and 2023, it was S/4,300 (about US\$1,200), S/4,400 (US\$1,250), S/4,600 (US\$1,300), and S/4,950 (US\$1,400), respectively.

worker (that serves as unemployment insurance). Under special regimes, some of the payroll taxes are lower (see Table 2).

Corporate Taxation Peru has multiple firm tax regimes with different corporate income tax (CIT) rates and payroll burdens, generating differentiated costs of reporting wages by sales and sector. Table 2 summarizes them. First, under the general regime, firms face a 29.5% CIT, and all reported wages and payroll contributions are fully deductible. Second, there is an agricultural regime. Firms under this regime face lower payroll contributions of 4–8% and a 15–20% CIT. Finally, there is a Small Firms regime, which applies to firms with sales below 1,700 tax units. These firms face 10% CIT for sales below 15 tax units and 29.5% for sales above 15 tax units.

Table 1: Personal Income Tax and Payroll Taxes Levied on Workers, MTR

	Personal Income Tax (PIT) (1)	Pensions (ONP/AFP) (2)
Taxable unit:	Income	Labor income
Income brackets: (in multiples of min. wage, $\bar{w}$)		
$[\bar{w}, 2.5\bar{w})$	0%	13%
$[2.5\bar{w}, 4\bar{w})$	8%	13%
$[4\bar{w}, 9\bar{w})$	14%	13%
$[9\bar{w}, 14.5\bar{w})$	17%	13%
$[14.5\bar{w}, 18\bar{w})$	20%	13%
$18\bar{w}+$	30%	13%
Levied on:	Workers	Workers

Notes: Table shows marginal tax rates (MTR). $\bar{w}$ is the monthly minimum wage (S/930 in 2021). PIT and the worker pension contribution (13%) are independent of the employer's tax regime (General, Agricultural, MYPE). Health insurance (EsSalud) is levied on firms and appears in Table 2. Unemployment insurance (CTS) is levied on the firm side as in Table 2. For the purpose of this paper, I assume that the only source of taxable income is labor income.

Table 2: Corporate Income Tax and Payroll Taxes Levied on Firms in 2020-2023, MTR

(1)	Health Insurance (EsSalud) (2)	Severance Pay (CTS) (3)	Corporate Income Tax (CIT) (4)
Taxable unit:	Labor income	Labor income	Profits
General Regime:			
All firms	9%	9.7%	29.5%
Small Firms Regime:			
Sales $\leq$ 1700 Tax Units	9%	9.7%	10% for sales $\leq$ 15 TU 29.5% for sales $>$ 15 TU
Agricultural Regime:			
$<$ 100 workers	4% (2020) 6% (2021-23)	9.7%	15% (2020) 15% (2021-23)
$\geq$ 100 workers	4% (2020) 7% (2021-22) 8% (2023)	9.7%	15% (2020) 15% (2021-22) 20% (2023)
Levied on:	Firms	Firms	Firms

Notes: The table shows marginal tax rates (MTR). If a rate is not accompanied by a year, it remained unchanged between 2020 and 2023. Payroll contributions refer to EsSalud (public health insurance). CTS (Compensación por Tiempo de Servicios) is a mandatory severance pay system equivalent to roughly one month's wage per year of service. Because deposits are calculated based on wages plus bonuses, the effective rate is approximately 9.7%. Pension contributions (13%) are uniform across regimes (see Table 1). The 2020 agricultural reform raised both payroll and corporate income taxes for firms with 100 or more workers. The MYPE regime is a special regime based on reported sales. Firms with annual sales below 1,700 tax units qualify as small enterprises and are eligible for this regime. The value of the tax unit varies by year—between 2020 and 2023, it was S/4,300 (about US\$1,200), S/4,400 (US\$1,250), S/4,600 (US\$1,300), and S/4,950 (US\$1,400), respectively. The threshold to enter the MYPE regime is approximately US\$2 million.

PUT Incentives PUT are attractive when the taxes avoided on underreported wages exceed the workers' valued benefits forgone from being formal and the firms' forgone corporate tax deductions.

Firm Side. Under Peruvian tax law, expenses without proper invoices or paystubs cannot be deducted from taxable profits. This includes wages paid under the table. Thus, the forgone corporate tax deduction is the marginal corporate tax rate (e.g., in the general regime, for each S/1 paid under the table, the forgone deduction is S/0.295). In practice, however, firms willing to misreport wages are often also willing to misreport deductible expenses (e.g., via fictitious invoices). This behavior is widely documented in developing-country tax systems (Best et al., 2015; Carrillo et al., 2017) and, if used, effectively reduces the corporate tax penalty of PUT. Thus, the true non-deductibility cost is likely fractional rather than full.

Worker Side. The personal income tax is a pure tax: reporting a higher wage and paying more tax does not grant access to additional benefits. So, the tax savings from receiving S/1 under the table equal the marginal personal income tax rate. Payroll contributions, by contrast, include a contributory component (such as pensions and severance) that accrues with reported wages, and a pure-tax component (like health care) that does not. Workers may not fully value the contributory component. As a result, the additional tax savings from receiving

S/1 under the table include the marginal rate of the pure-tax component of payroll contributions. The cost, on the other hand, is the value the worker places on the forgone payroll benefits.

In the model, I capture heterogeneity in the valuation of payroll benefits with parameter $\theta \in [0, 1]$.⁵ Let τ be the statutory tax rate (PIT + payroll tax) on reported wages, t the corporate tax rate, and $d \in [0, 1]$ the fraction of PUT effectively deducted via disguised expenses. Then, per sol shifted to PUT, the joint surplus is as follows:

$$\Delta S = \underbrace{\tau}_{\text{tax saving}} - \left(\underbrace{(1-d)t}_{\text{forgone corporate deduction}} + \underbrace{\theta}_{\text{value of forgone benefits}} \right). \quad (1)$$

PUT is chosen for that sol whenever $\Delta S > 0$. All else equal, higher θ (more valuation of payroll benefits) reduces the incentive to underreport, while higher d (more deductibility) increases it⁶.

I formalize these PUT incentives in the optimal income tax model in Section 4. But, before turning to theory, I first show that PUT can be empirically recovered in the data. Section 3 develops a distribution-matching approach based on optimal transport to estimate the extent and structure of wage underreporting.

3. Estimating PUT

In this section, I measure PUT in Peru by comparing two kinds of data: administrative payroll records, which contain the wage each employer reports, and two household surveys, which record the wage each worker self-reports. The two sources describe the same workers but cannot be linked, since both are anonymized to protect privacy. I proceed in two steps. First, within cells of comparable workers, I compare the two wage distributions at three points: the mean, the median and the 30th percentile of self-reported wages (Section 3.2). These comparisons show how far apart the two distributions are, and they do not depend on which survey respondent corresponds to which payroll worker. Second, I separate the share of workers who receive PUT from how much they receive (Section 3.3). This requires knowing which self-reported wage belongs to which payroll worker, so instead of assuming a pairing, I report lower bounds that hold for every pairing consistent with the data.

3.1. Data

Sources. The payroll is the electronic payroll (Planilla Electrónica), collected jointly by the Ministry of Labor and Employment Promotion (MTPE) and the tax authority (SUNAT). Every private employer reports each of its workers every month, so the payroll covers all formal private employment, about seven million workers in 2022. For each worker and month, it records the gross wage the employer reports, the worker’s sex, age group and education, and the employer’s sector, location and number of workers (Appendix 7.1). I use 2020–2023 and one observation per worker and year: the median of the worker’s monthly gross wage over the months in which the worker appears. Firm size is the employer’s number of workers in the payroll. Section 5 uses the monthly records.

⁵Hiding S/1 saves τ in taxes but forfeits a marginal valued benefit equal to the slope of the forgone-benefit schedule at the current hiding level. For the per-dollar entry margin used here (starting from full formality), I normalize that slope to θ , so the equation below replaces the marginal term by θ . If one evaluates at other hiding levels, replace θ by the appropriate marginal value at that level (which will also be a function of θ).

⁶This static surplus comparison is a reduced-form version of the more general environment in Section 4, where the cost of underreporting enters through a convex function of hidden earnings.

The main survey is the Encuesta Permanente de Empleo Nacional (EPEN) of the National Institute of Statistics and Informatics (INEI), for 2022 and 2023, the years in which its public microdata overlap the payroll. It records the main-job wage of employees in about 97,000 interviews a year. The second is INEI’s Encuesta Nacional de Hogares (ENAHO), about a quarter as large, which covers 2020–2023 and serves as a check (Appendix 7.8). In both, I use the gross monthly income from the respondent’s main job, which, like the payroll’s wage, is gross of pension contributions (Appendix Figure A1).

Harmonization. Before any comparison, I harmonize the two sources to the same population: formal employees of private employers, in their main job, paid within a common estimation window. In both surveys, I keep employees of private employers whose health insurance is paid by their employer, the survey counterpart of a worker in the payroll. Both surveys ask every insured respondent who pays for each insurance: the workplace, the respondent, a family member, or a pension.⁷ Both samples exclude public administration, since the payroll covers only private employers. The estimation window keeps wages from just below the lowest minimum wage in force during the year (0.95 times it) to the 96th percentile of self-reported wages above the minimum (S/6,000 in EPEN). Above the upper cut, the payroll has more than twice the survey’s share of workers, and the survey has too few respondents to describe the top of the distribution (Appendix 7.2).⁸ The final samples have 4.8 million payroll workers in 2022 and 3.8 million in 2023,⁹ and the EPEN samples have 22,931 and 24,020 interviews; the ENAHO samples are about a quarter as large.

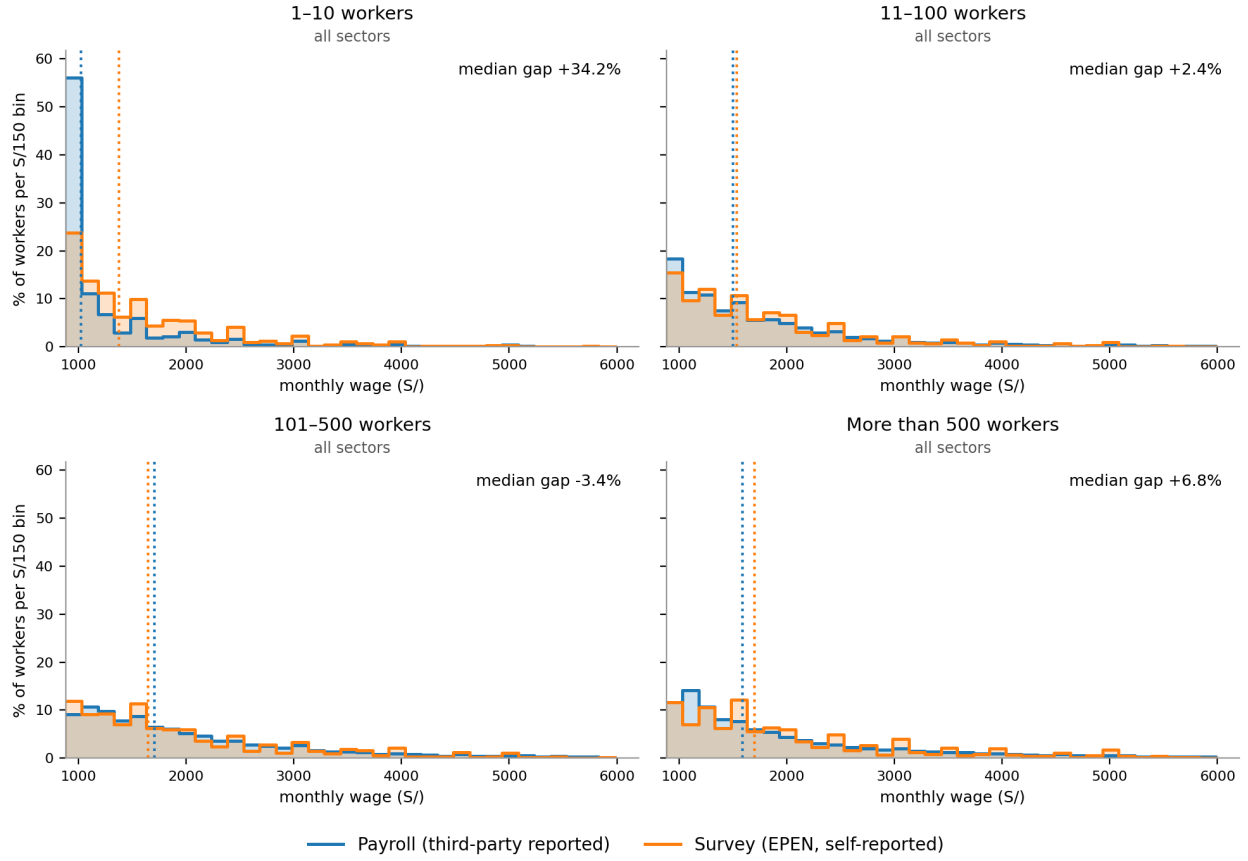
Descriptive statistics. Figure 1 plots the raw distributions of third-party reported and self-reported wages by firm size, before any cells or reweighting. At micro firms (1–10 workers), reported wages pile up at the minimum wage while self-reported wages spread above it: 53% of micro-firm payroll workers are reported at the minimum wage, against 15% of micro-firm survey respondents (Table 3). The largest vertical gap between the two cumulative distributions at micro firms is 33 percentage points (Appendix Figure A3); Section 3.3 shows that this gap is the lower bound on the share of workers who receive PUT, treating micro firms as a single cell. At larger firms, the two distributions are close. The gap at micro firms is present at every level of education: 45% of micro-firm workers with completed tertiary education are reported at the minimum wage, against 13% of their survey counterparts (Table 3 and Figure 2). By age, the two distributions are close for workers under 60 and far apart for workers over 60 (Appendix Figures A5 and A6). These gaps are differences between two distributions; Section 3.2 sets out when they can be read as PUT.

⁷Defining formality by any health-insurance affiliation, whoever pays for it, adds respondents insured through a family member or a pension, whose current job need not be on any payroll. Among workers over 60, more than a third are insured this way (Appendix Table A1). The results are similar under the broader definition, and slightly larger at micro firms under the one I use.

⁸The lower cut removes payroll records of workers present only part of a month, whose reported wage runs to zero. The cuts remove more payroll records than survey responses below the lower cut (25% against 5% in 2022) and slightly more above the upper cut (4% against 3%). All results are for workers inside the window.

⁹The 2023 payroll available to me covers January, February, April, May and June.

Figure 1: Third-party reported and self-reported wage distributions, by firm size



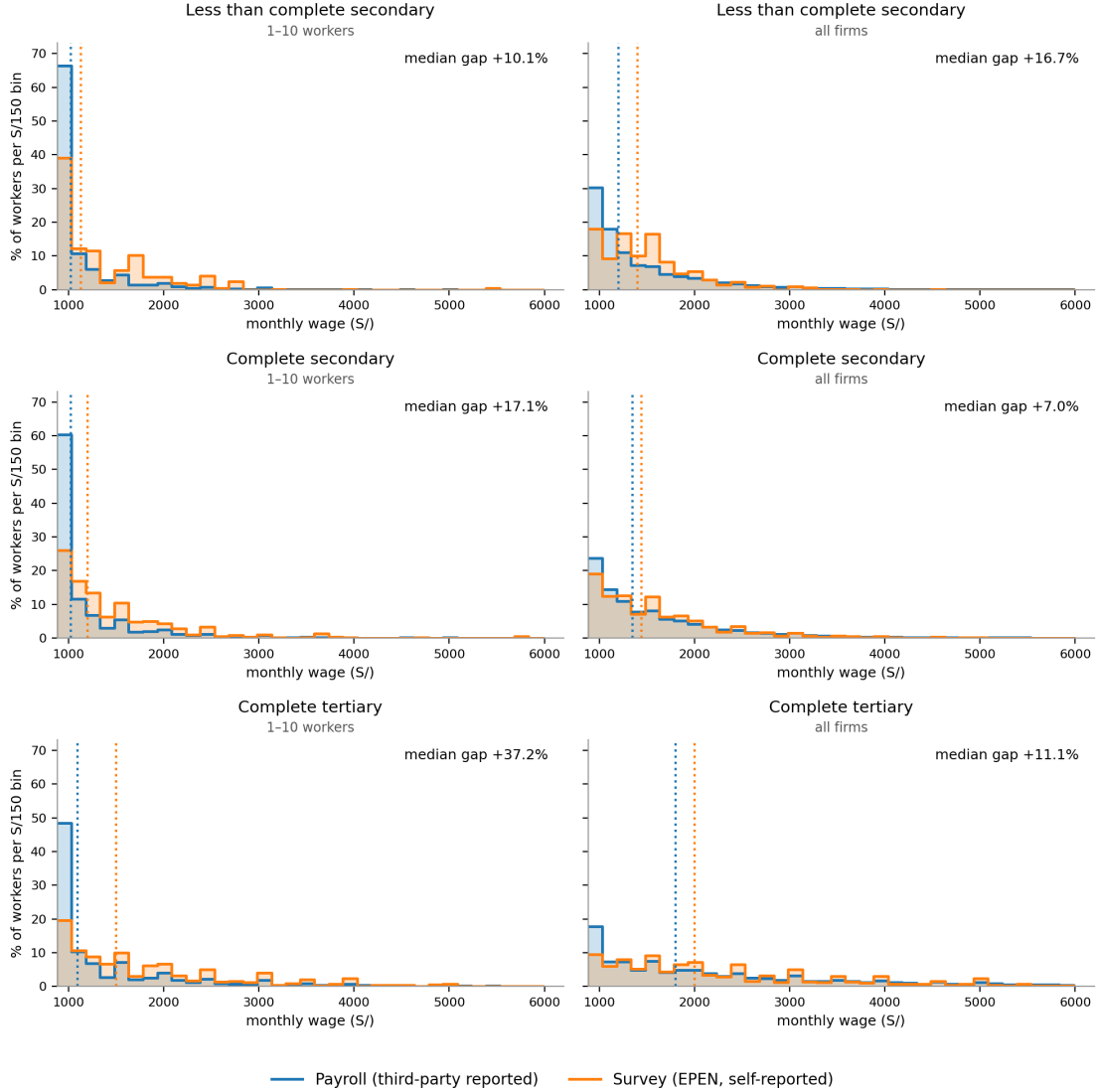
Notes: Share of workers in each S/150 bin of the monthly gross wage, private formal employees, 2022. Blue: payroll (third-party reported). Orange: EPEN (self-reported). Dotted vertical lines are the medians; each panel reports the gap between them as a percentage of the payroll median. EPEN weighted. No cells and no reweighting.

Table 3: Share of workers at the minimum wage (%)

Firm size	2022		2023	
	Payroll	EPEN	Payroll	EPEN
All	16.6	8.6	16.4	12.5
1-10	52.6	15.1	52.6	19.4
11-100	14.0	9.1	12.7	14.4
101-500	4.7	7.1	3.4	10.4
More than 500	4.4	6.6	2.8	9.5
1-10, completed tertiary	45.3	13.0	44.8	15.1

Notes: Share of workers whose third-party reported (payroll) or self-reported (EPEN) monthly wage is within 1% of the minimum wage in force; in 2022, when the minimum wage rose from S/930 to S/1,025 on May 1, either value. Completed tertiary uses the payroll's education record. Private formal employees in the estimation window; EPEN weighted.

Figure 2: Third-party reported and self-reported wage distributions, by education



Notes: As Figure 1. Rows: less than complete secondary, complete secondary, and complete tertiary (including postgraduate). Left: micro firms (1–10 workers). Right: all firms.

3.2. Cell-by-cell comparison of wage distributions

Within cells of comparable workers, I compare the two wage distributions at three points: the mean, the median and the 30th percentile of self-reported wages. Cells are defined by firm size (1–10, 11–100, 101–500 and more than 500 workers) and sector (agriculture, mining, manufacturing, construction, commerce and services): 24 cells. Within each cell, I reweight the survey so that its shares by age group, sex and region (Lima or not) match those of the payroll. Every payroll cell contains thousands of workers, so the survey determines how finely cells can be drawn. With these 24 cells, the median cell has 554 survey respondents; adding age groups to the cell definition would leave a quarter of cells with fewer than 30 (Appendix Table A2).

For a payroll worker, $\hat{w}$ is the third-party reported wage (the reported wage, for short) and w the true wage, the amount the employer pays, which no dataset records. Payments under the table are $PUT = w - \hat{w}$. Within

a cell c , the payroll identifies the distribution of reported wages, with cumulative distribution function $F_{\hat{w},c}$, and the survey identifies the distribution of self-reported wages, $F_{\tilde{w},c}$. The key assumption is that, within each cell, the self-reported wages of survey respondents follow the same distribution as the true wages of payroll workers, so that any gap between the two distributions is PUT. This requires three things. First, survey respondents in a cell must represent the cell’s payroll workers; reweighting by age, sex and region helps with this. Second, respondents must report their true wage, including any part paid under the table. Third, they must be classified in the right cell. I state these as one assumption.

Assumption 1 (the survey represents true wages). *Within each cell and inside the estimation window, $F_{\tilde{w},c} = F_{w,c}$: the distribution of self-reported wages among the reweighted survey respondents equals the distribution of true wages among the cell’s payroll workers.*

If respondents report less than their true wage, for example by giving the survey their reported wage, or if the survey misses high earners,¹⁰ the distribution of self-reported wages lies below the distribution of true wages. The gaps I measure are then smaller than true PUT, and every estimate below is a lower bound.¹¹ Only respondents who report more than they are paid, for example by rounding up a wage at the minimum or by including pay the payroll does not record, would push the estimates up. This is the main threat to the estimates, and Section 3.3 tests for it.

Comparison of mean, median and excess mass. I follow Kumler et al. (2020) and compare the two distributions within each cell at three points, none of which depends on which payroll worker corresponds to which respondent:

$$\text{mean gap}_c = \frac{\bar{\tilde{w}}_c - \bar{\hat{w}}_c}{\bar{\tilde{w}}_c}, \quad \text{median gap}_c = \frac{q_c^{\tilde{w}} - q_c^{\hat{w}}}{q_c^{\tilde{w}}}, \quad \text{excess mass}_c = F_{\hat{w},c}(q_c^{30}) - F_{\tilde{w},c}(q_c^{30}),$$

where bars denote means, q medians, and q_c^{30} the 30th percentile of self-reported wages in the cell. Group statistics average the cells of the group, weighting each by its number of payroll workers.

Under Assumption 1, the mean gap equals mean PUT as a share of the mean reported wage. It nets workers paid less than they are reported against those paid more, so it can be small even when many workers receive PUT. The median gap and the excess mass are less sensitive to the top of the distribution, where surveys under-represent high wages. The excess mass is the share of payroll workers reported at or below the survey’s 30th percentile, minus the respondents’ own share at or below it.¹²

Tables 4 and 5 report the three statistics. Across all private formal employees, self-reported wages exceed third-party reported wages by 5.5% at the mean and 8.4% at the median in 2022, and at or below the survey’s 30th percentile the payroll has an excess mass of 7.8 percentage points of workers. At micro firms, the gaps are

¹⁰The estimation window cuts the payroll on the reported wage and the survey on the self-reported wage. At the top, if PUT is non-negative, the cut keeps in the payroll the workers reported below S/6,000 but paid above it, and drops their counterparts from the survey, which also makes the survey understate.

¹¹Formally, the survey understates when $F_{\tilde{w},c}(x) \geq F_{w,c}(x)$ at every wage x . Every statistic and lower bound below, except the one on the intensive margin, falls when $F_{w,c}$ rises at some wage, so computing it with $F_{\tilde{w},c}$ gives a lower bound on its true value. The lower bound on the intensive margin needs Assumption 1 to hold exactly.

¹²Without ties at q_c^{30} this is the measure of Kumler et al. (2020), the share of payroll workers below the percentile minus 30. I compare both distributions at the same point because survey respondents heap at the minimum wage and at round numbers. Appendix Table A5 reports the 15th to 40th percentiles.

Table 4: Mean and median gaps between self-reported and third-party reported wages within cells (%)

	Mean gap						Median gap					
	2020		2021		2022		2023		2020		2021	
	ENAO	EPEN	ENAO	EPEN	ENAO	EPEN	ENAO	EPEN	ENAO	EPEN	ENAO	EPEN
Firm size												
All	4.2 (1.3)	1.7 (1.1)	2.8 (1.0)	5.5 (0.7)	1.8 (1.0)	5.3 (0.7)	7.6 (1.9)	5.9 (1.6)	8.7 (1.3)	8.4 (1.1)	9.3 (1.4)	10.3 (1.0)
1–10	19.7 (4.1)	19.2 (2.6)	18.5 (2.6)	22.5 (2.1)	17.7 (2.4)	27.1 (2.0)	27.8 (5.1)	35.1 (4.4)	33.5 (3.8)	31.2 (2.6)	39.3 (3.7)	45.9 (1.9)
11–100	1.3 (1.8)	–1.4 (1.9)	0.1 (1.6)	1.1 (1.1)	–3.5 (1.3)	–0.7 (0.9)	4.4 (2.9)	–2.4 (2.6)	2.8 (1.8)	1.7 (1.5)	–1.3 (1.5)	–1.6 (1.0)
101–500	–0.7 (2.4)	–8.5 (2.1)	–4.9 (2.2)	–1.4 (1.3)	–5.0 (2.1)	–5.5 (1.2)	–0.1 (2.4)	–7.3 (2.6)	–4.2 (1.9)	–0.9 (1.7)	–2.1 (3.3)	–5.8 (2.0)
More than 500	–0.4 (1.9)	–1.1 (1.9)	–0.2 (1.7)	2.6 (1.2)	–0.9 (1.7)	1.7 (1.0)	1.7 (3.2)	1.0 (2.7)	5.7 (2.0)	5.1 (2.0)	3.7 (2.6)	4.7 (2.4)
Age												
Under 30	1.7 (1.6)	4.4 (2.2)	3.4 (1.7)	6.2 (1.1)	5.3 (1.8)	4.5 (1.1)	8.5 (2.2)	8.3 (2.8)	10.8 (2.5)	8.2 (1.5)	10.6 (2.8)	6.8 (1.4)
30–60	2.3 (1.6)	–0.8 (1.4)	1.1 (1.3)	4.6 (0.9)	0.7 (1.1)	4.6 (0.9)	4.2 (2.3)	2.8 (1.8)	6.8 (1.6)	10.6 (1.2)	7.0 (1.6)	9.1 (1.5)
Over 60	37.6 (13.0)	11.0 (5.4)	14.8 (6.3)	23.3 (7.1)	8.3 (5.5)	25.4 (5.8)	53.3 (23.2)	24.0 (5.9)	22.7 (9.6)	20.4 (10.6)	14.6 (8.5)	32.1 (6.7)
Education, micro firms (1–10 workers)												
Less than complete secondary	0.3 (3.9)	14.1 (5.9)	14.1 (5.4)	16.3 (5.5)	19.2 (8.5)	16.9 (4.5)	7.8 (4.3)	17.6 (7.4)	15.7 (10.7)	14.5 (5.2)	27.0 (12.0)	16.4 (6.3)
Complete secondary	24.0 (6.0)	16.3 (3.3)	18.5 (3.2)	16.8 (3.1)	13.5 (2.7)	25.1 (3.2)	27.8 (6.4)	26.7 (4.4)	28.2 (4.4)	19.5 (3.1)	30.6 (3.7)	34.0 (4.9)
Complete tertiary	20.0 (6.2)	25.2 (5.5)	23.9 (4.9)	24.4 (3.0)	21.5 (4.0)	27.0 (3.0)	42.8 (6.8)	46.3 (7.9)	44.8 (9.6)	40.1 (4.0)	47.0 (6.6)	46.2 (5.9)

Notes: Mean gap: (mean self-reported – mean reported wage)/mean reported wage. Median gap: the same for medians. Within each cell; age and education groups pool the cells of the group. Bootstrap standard errors in parentheses (200 replications resampling primary sampling units within strata). Formal employees: health insurance paid by the employer, in both surveys. Private formal employees in the estimation window. Cells: firm size (1–10, 11–100, 101–500, more than 500 workers) by sector (agriculture, mining, manufacturing, construction, commerce, services); within cells, survey weights are reweighted to the payroll's shares by age group, sex and Lima. Group statistics average cells weighted by payroll workers.

Table 5: Excess mass of the payroll at the survey’s 30th percentile (percentage points)

	2020	2021	2022		2023	
	ENAH0	ENAH0	ENAH0	EPEN	ENAH0	EPEN
Firm size						
All	7.9	6.4	9.3	7.8	7.7	5.6
	(1.5)	(1.1)	(1.6)	(0.7)	(1.0)	(0.7)
1–10	27.9	31.2	29.3	29.0	32.0	30.6
	(2.3)	(3.3)	(6.0)	(1.5)	(1.7)	(1.7)
11–100	1.9	1.2	4.5	2.0	0.8	–1.6
	(3.3)	(1.9)	(1.9)	(1.0)	(1.3)	(1.1)
101–500	2.3	–6.3	–1.0	–0.6	–3.8	–5.1
	(2.1)	(1.8)	(3.5)	(1.6)	(2.5)	(1.5)
More than 500	2.8	1.8	6.7	4.3	3.3	0.6
	(2.8)	(1.8)	(2.1)	(1.2)	(1.8)	(1.1)
Age						
Under 30	8.8	8.6	6.7	6.4	8.2	4.8
	(2.4)	(2.6)	(2.2)	(1.2)	(2.7)	(1.2)
30–60	5.1	5.3	7.9	7.8	6.9	5.8
	(1.8)	(1.2)	(1.5)	(0.8)	(1.1)	(0.9)
Over 60	31.7	26.6	19.2	20.4	19.1	24.5
	(9.6)	(4.2)	(7.8)	(4.9)	(7.8)	(2.8)
Education, micro firms (1–10 workers)						
Less than complete secondary	34.8	32.9	16.0	6.7	45.5	30.9
	(18.4)	(5.7)	(14.2)	(13.5)	(13.2)	(5.1)
Complete secondary	29.2	29.5	34.3	30.5	36.4	33.8
	(6.3)	(4.0)	(7.9)	(3.0)	(3.4)	(2.6)
Complete tertiary	27.1	30.9	30.4	27.2	30.1	29.5
	(5.2)	(3.6)	(7.5)	(2.0)	(2.1)	(1.8)

Notes: Share of payroll workers reported at or below the 30th percentile of self-reported wages, minus the respondents’ own share at or below it. Within each cell; age and education groups pool the cells of the group. Bootstrap standard errors in parentheses (200 replications resampling primary sampling units within strata). Formal employees: health insurance paid by the employer, in both surveys. Private formal employees in the estimation window. Cells: firm size (1–10, 11–100, 101–500, more than 500 workers) by sector (agriculture, mining, manufacturing, construction, commerce, services); within cells, survey weights are reweighted to the payroll’s shares by age group, sex and Lima. Group statistics average cells weighted by payroll workers.

22.5%, 31.2% and 29.0 points (27.1%, 45.9% and 30.6 in 2023). At firms with more than 10 workers, the gaps are small or negative: in 2022 the mean gap is between -1.4% and 2.6% , and in 2023 it falls to -5.5% at firms with 101–500 workers. The gaps are present at every level of education within micro firms. By age, they are largest for workers over 60, though measured with less precision. One possible reason is that workers close to retirement have either secured their pension or will not obtain one, so the reported wage matters less to them.

In most groups, the mean gap is smaller than the median gap. The mean is sensitive to the top of each cell, where the payroll’s distribution has a longer right tail than the survey’s: surveys under-represent high wages, so at the top of the cell the self-reported wages fall below the third-party reported ones. These negative gaps pull the mean down more than the median. ENAHO shows the same pattern in every year from 2020 to 2023, with smaller mean gaps at micro firms than EPEN in the two years both surveys cover (Appendix 7.8).

3.3. Bounds on the extensive and intensive margins of PUT

The mean, the median and the 30th percentile describe how far apart the two distributions are, but not how PUT is spread across workers: the same gap can come from a few workers receiving large payments or from many workers receiving small ones. Telling the two apart shows whether PUT is a common practice or one confined to a few workers, and the share of workers who receive it is what direct surveys measure when they ask workers whether they are paid under the table.

The *extensive margin* is the share of workers who receive PUT, $\Pr(\text{PUT} > 0)$. The *intensive margin* is how much they receive: the average PUT among recipients, as a share of their reported wage, $E[\text{PUT}/\hat{w} \mid \text{PUT} > 0]$. Separating the two requires knowing which self-reported wage belongs to which payroll worker. Both sources are anonymized to protect privacy, so they cannot be linked one-to-one. Within each cell, the data identify the distribution of reported wages and, under Assumption 1, the distribution of true wages, but not their joint distribution. Any joint distribution with these two marginals, which I call a *pairing* (a copula), is consistent with the data. The most common choice is rank invariance: the worker at the p -th percentile of reported wages has the p -th percentile of true wages (Heckman et al., 1997). Instead of assuming a pairing, I consider every pairing consistent with the two observed marginal distributions, and report lower bounds that must hold for all of them. Each bound solves an optimal transport problem: for the extensive margin, for example, optimal transport finds the pairing with the fewest workers whose self-reported wage exceeds their reported wage. A lower bound is enough to tell whether PUT is a common practice and whether direct surveys capture it.

For any single pairing, the extensive margin times the intensive margin is the average PUT across all workers, counting those whose true wage is at or below the reported wage as zero: the *average PUT rate*, $\rho = E[(\text{PUT}/\hat{w})^+]$. Multiplying the two bounds, however, does not give the lower bound on this average, because each bound is attained by a different pairing. Like the bounds on the two margins, the lower bound on the average PUT rate solves an optimal transport problem, and its solution is rank invariance.

Proposition 1 (Lower bounds). *Fix a cell and let $F_w = F_{\bar{w}}$, as under Assumption 1.¹³ Over all pairings of reported and true wages:*

¹³The proof also uses that reported wages are bounded away from zero and that the mean true wage is finite, as holds inside the estimation window; $F^{-1}(u) = \inf\{x : F(x) \geq u\}$ is the quantile function. With the empirical distributions, which have finite support, every minimum below is attained.

(i) the smallest extensive margin has a closed form,

$$\underline{e} = \sup_x [F_{\hat{w}}(x) - F_w(x)];$$

(ii) when $\underline{e} > 0$, the smallest intensive margin,

$$\underline{i} = \min_{\pi} \frac{E_{\pi}[(\text{PUT}/\hat{w})^+]}{\Pr_{\pi}(\text{PUT} > 0)},$$

where π ranges over all pairings, has no closed form;

(iii) the smallest average PUT rate has a closed form and is attained by rank invariance,

$$\underline{\rho} = \int_0^1 \left(\frac{F_w^{-1}(u)}{F_{\hat{w}}^{-1}(u)} - 1 \right)^+ du.$$

Each smallest value is attained by some pairing, so none can be raised without an assumption on the pairing.

The proof is in Appendix 7.5. For the extensive margin (i): at any wage x , the payroll reports a share $F_{\hat{w}}(x)$ of workers at or below x , but only a share $F_w(x)$ is paid that little. Whatever the pairing, the difference must be workers reported at or below x but paid more than x , and so paid more than they are reported: they receive PUT. For example, if 60% of a cell's workers are reported at or below S/1,100 but only 40% are paid that little, at least 20% receive PUT. The lower bound is the largest such difference across wages (Makarov, 1981; Fan and Park, 2010). For the intensive margin (ii): I search over all pairings for the one that gives recipients the smallest average PUT. Because the pairing changes both who receives PUT and how much, there is no closed form; the search is solved as a short sequence of optimal transport problems (Dinkelbach, 1967). For the average PUT rate (iii): the smallest value comes from pairing workers by rank: the lowest self-reported wage with the lowest reported wage, the second lowest with the second lowest, and so on. This is rank invariance (Cambanis et al., 1976). Whenever a pairing gives a higher true wage to a worker reported lower than another, swapping their two true wages never raises their combined PUT rate, so removing every such crossing can only lower the average. For (i) and (iii), solving the transport problems directly gives exactly the closed-form values (Appendix 7.6).

Table 6 reports the lower bounds, for EPEN in 2022 and 2023 and for ENAHO in 2020–2023. At least 13.2% of private formal employees inside the estimation window receive PUT, and at least 33.5% at micro firms (13.7% and 38.0% in 2023). Recipients receive on average at least 9.7% of their reported wage, and at least 25.7% at micro firms (11.9% and 33.8% in 2023). The average PUT rate is at least 7.7% of the reported wage, and 22.0% at micro firms (8.2% and 27.1% in 2023). By sector, agriculture, construction and mining stand out. At firms with 101–500 workers the lower bounds are small: in 2022, two to three times the level that sampling noise from finite survey cells alone produces.¹⁴ The lower bounds do not multiply: 13.2% times 9.7% is far below the lower bound on the average PUT rate, because each lower bound is attained by a different pairing.

Under rank invariance, the most common pairing, the extensive margin is 51.2% and the intensive margin is 15.1% in 2022 (77.2% and 28.6% at micro firms), and the average PUT rate equals its lower bound, since rank

¹⁴Sampling noise is not measurement error: it would arise even if every respondent reported their wage exactly. Survey cells are finite, and sampling noise makes two distributions look more different than they are, which can push every lower bound up. Replacing the survey with a subsample of the payroll of the same size, so that the two distributions coincide, the method returns a lower bound of 1.6% on the extensive margin and 0.6% on the average PUT rate for the economy in 2022 (Appendix Table A8).

Table 6: Extensive margin, intensive margin and average PUT rate: lower bounds over all pairings (%)

Firm size	Ext.						Int.						Avg. PUT rate					
	2020	2021	2022	2023	2020	2021	2022	2023	2020	2021	2022	2023	2020	2021	2022	2023	2020	2021
	ENAO	ENAO	EPEN	ENAO	EPEN	ENAO	EPEN	ENAO	ENAO	EPEN	ENAO	EPEN	ENAO	ENAO	EPEN	ENAO	ENAO	EPEN
All	15.8 (14.5) [11.4]	16.5 (15.3) [12.6]	14.2 (12.9) [9.9]	13.2 (12.3) [10.8]	15.2 (13.9) [11.6]	13.7 (12.9) [11.9]	9.1 (7.3) [6.4]	8.5 (7.2) [6.2]	9.2 (8.2) [6.8]	9.7 (8.9) [8.5]	8.5 (7.6) [6.4]	11.9 (11.0) [10.8]	7.2 (5.5) [5.0]	6.5 (5.4) [4.6]	7.4 (6.1) [5.5]	7.7 (6.8) [6.7]	6.6 (5.2) [4.9]	8.2 (7.5) [7.3]
1–10	40.2 (36.7) [33.6]	44.3 (41.9) [39.7]	35.9 (32.4) [28.7]	33.5 (31.5) [29.3]	43.5 (40.7) [38.1]	38.0 (36.3) [35.0]	23.6 (17.6) [16.6]	23.2 (19.1) [18.2]	24.3 (19.8) [19.0]	25.7 (22.1) [22.3]	23.2 (20.5) [17.7]	33.8 (30.3) [31.0]	20.1 (15.3) [13.8]	21.1 (16.9) [16.7]	20.8 (17.3) [15.7]	22.0 (18.9) [19.0]	20.4 (16.1) [15.1]	27.1 (24.5) [24.8]
11–100	9.5 (7.5) [5.2]	10.6 (9.1) [6.6]	7.4 (5.0) [2.0]	6.3 (5.1) [3.6]	7.1 (5.2) [2.9]	4.8 (3.6) [2.3]	4.6 (2.8) [1.3]	3.3 (2.1) [0.9]	5.0 (3.2) [2.1]	5.2 (4.5) [4.0]	5.2 (2.3) [1.6]	5.3 (4.5) [4.2]	3.4 (1.4) [0.3]	2.1 (0.8) [0.0]	3.6 (1.1) [1.1]	3.7 (2.6) [2.6]	2.3 (1.1) [0.7]	2.4 (1.8) [1.5]
101–500	8.0 (5.2) [2.5]	5.1 (3.4) [1.5]	6.7 (4.7) [2.4]	4.7 (3.3) [2.2]	4.3 (2.2) [0.6]	3.1 (2.2) [1.4]	5.5 (3.2) [1.7]	2.8 (1.4) [0.3]	4.9 (2.7) [1.8]	4.1 (3.0) [2.7]	3.2 (1.9) [0.3]	3.0 (2.4) [1.9]	3.7 (1.6) [0.5]	1.5 (0.1) [0.0]	3.2 (1.1) [1.1]	2.4 (1.5) [1.2]	1.7 (0.2) [0.0]	1.0 (0.6) [0.4]
More than 500	9.8 (7.0) [3.7]	10.0 (7.2) [3.4]	10.7 (8.4) [5.7]	10.8 (9.4) [7.8]	8.7 (6.3) [3.6]	10.3 (8.9) [7.7]	5.1 (2.9) [1.7]	5.0 (3.7) [2.5]	5.8 (4.7) [3.1]	6.4 (5.3) [5.0]	4.7 (3.1) [2.4]	6.0 (5.1) [4.5]	3.9 (1.6) [1.1]	3.6 (1.9) [1.3]	4.6 (3.0) [2.2]	5.1 (4.1) [3.8]	3.4 (1.5) [1.4]	4.3 (3.2) [3.0]
Sector																		
Agriculture	18.9 (14.2) [9.2]	31.1 (27.5) [23.0]	34.4 (30.5) [27.4]	36.8 (34.5) [32.5]	36.9 (33.7) [30.0]	35.3 (32.4) [29.7]	5.6 (3.4) [2.4]	13.7 (11.0) [10.7]	17.1 (14.1) [13.5]	18.8 (17.2) [16.2]	18.2 (15.9) [15.4]	15.8 (13.7) [12.8]	4.6 (2.2) [1.7]	12.6 (10.4) [9.9]	15.8 (13.6) [12.4]	17.8 (15.6) [15.3]	16.8 (14.1) [14.2]	14.3 (12.5) [11.3]
Mining	22.2 (17.1) [10.9]	20.1 (14.5) [10.3]	17.0 (13.2) [10.3]	19.3 (16.2) [12.7]	15.6 (11.9) [8.8]	17.5 (14.1) [9.9]	22.2 (15.3) [13.1]	18.9 (11.7) [7.2]	14.7 (8.8) [4.0]	14.8 (11.3) [9.3]	17.6 (8.8) [8.8]	18.1 (14.3) [13.1]	16.8 (9.8) [9.9]	15.4 (6.0) [6.0]	10.9 (7.2) [6.6]	11.3 (5.2) [5.2]	12.8 (10.3) [10.3]	13.8 (10.3) [9.0]
Manufacturing	13.8 (10.9) [8.5]	14.6 (12.0) [8.4]	9.5 (6.2) [4.2]	12.1 (10.0) [7.7]	11.8 (8.6) [5.8]	11.7 (9.8) [8.7]	9.2 (5.5) [4.3]	5.7 (3.1) [2.0]	5.1 (2.0) [0.0]	7.3 (5.5) [4.9]	7.4 (2.9) [0.4]	10.1 (8.2) [8.0]	7.0 (4.2) [2.6]	4.4 (2.1) [1.0]	3.8 (1.3) [0.0]	5.6 (3.0) [3.4]	5.4 (1.1) [0.0]	7.1 (5.4) [5.4]
Construction	26.0 (8.5) [17.1]	17.1 (12.0) [8.4]	31.2 (24.6) [15.7]	18.0 (14.8) [11.0]	20.3 (16.1) [8.9]	16.7 (13.7) [10.6]	19.8 (13.1) [6.6]	12.1 (8.0) [3.4]	25.6 (17.1) [15.7]	16.6 (13.7) [12.9]	16.9 (12.3) [8.7]	16.3 (12.9) [12.3]	19.0 (12.2) [7.3]	10.1 (5.3) [3.0]	24.8 (18.2) [15.6]	15.4 (9.3) [12.0]	14.3 (9.3) [7.1]	13.8 (10.9) [10.0]
Commerce	17.6 (14.4) [11.0]	20.6 (18.5) [17.2]	14.8 (11.9) [9.9]	12.1 (10.4) [8.9]	18.9 (16.4) [13.5]	15.5 (14.0) [13.5]	7.5 (4.9) [3.3]	8.9 (5.7) [4.4]	8.8 (6.9) [4.8]	11.1 (8.4) [7.7]	7.6 (4.9) [3.5]	13.5 (11.5) [11.4]	5.0 (2.2) [1.9]	6.5 (4.4) [3.2]	6.0 (4.0) [2.9]	7.9 (5.2) [5.1]	5.8 (3.4) [2.6]	8.6 (6.8) [6.8]
Services	13.5 (11.5) [9.0]	12.9 (11.1) [8.8]	9.1 (7.2) [5.0]	8.9 (7.8) [6.5]	11.6 (9.6) [8.1]	10.5 (9.5) [8.6]	7.7 (5.5) [4.2]	6.9 (5.5) [4.4]	5.8 (4.6) [3.6]	6.8 (5.6) [5.5]	6.4 (4.9) [4.3]	10.4 (9.1) [9.1]	6.1 (3.7) [3.0]	5.0 (3.2) [2.8]	4.4 (2.7) [2.5]	5.1 (4.2) [3.9]	4.7 (2.9) [2.8]	6.8 (5.5) [5.7]

Notes: Ext.: extensive margin. Int.: intensive margin. Avg. PUT rate: average PUT rate. Each entry is the least value over all joint distributions of reported and true wages consistent with the two observed distributions within cells (pairings). Extensive: share of workers receiving PUT. Intensive: average PUT among recipients, as a share of their reported wage. Average PUT rate: average PUT across all workers as a share of the reported wage, counting workers whose true wage is at or below the reported wage as zero; it is attained by rank invariance. One-sided 95% lower confidence bounds. In parentheses, naive: the estimate minus 1.645 bootstrap standard errors. In brackets, conservative: the bound of Chernozhukov et al. (2013) for the extensive margin, and subsampling for the intensive margin and the average PUT rate. Both resample the survey's primary sampling units within strata and redo the reweighting in each draw. Formal employees: health insurance paid by the employer, in both surveys. Private formal employees in the estimation window. Cells: firm size (1–10, 11–100, 101–500, more than 500 workers) by sector (agriculture, mining, manufacturing, construction, commerce, services); within cells, survey weights are reweighted to the payroll's shares by age group, sex and Lima. For a group, the lower bounds on the extensive margin and on the average PUT rate average the cell lower bounds, weighted by payroll workers; the lower bound on the intensive margin chooses the pairings of all the group's cells jointly.

invariance attains it (Appendix Table A7).

The results are consistent with a direct survey that we ran across Latin America in 2024 (Feinmann et al., 2025a), which asks workers whether they receive PUT and how much. I compare it with my estimates for 2023, the closest year in my data. In Peru, 10% of formal employees say they receive PUT, somewhat below my lower bound of 13.7% on the extensive margin, as expected when people are asked about an illegal practice (Tourangeau and T Yan, 2007). Those who say they receive PUT get about 28% of their reported wage this way, above my lower bound of 11.9% on the intensive margin. In other words, the survey falls short in how many workers admit to PUT, not in how much those who admit it say they receive.

Robustness to survey errors. The lower bounds could also reflect errors in the survey. There are two kinds. The first is measurement error: the respondent’s report differs from the true wage, either through small overstatements or through reporting noise in either direction. The second is sampling noise, which comes from the finite number of respondents in each survey cell and would arise even if every respondent reported exactly.

First, consider measurement error. The main concern is that respondents overstate their wage, which would look like PUT. Validation studies that compare surveys with administrative records (Bound et al., 2001; Abowd and Stinson, 2013) find that low earners overstate in the United States (Bound and Krueger, 1991; Bollinger, 1998), and Paulus (2015) finds the same in Estonia. I check for overstatement where the true wage is known: public employees in education and health, whose payroll records their whole gross pay and who should not receive PUT. They do not overstate. Their self-reported wages lie on average 13% below the payroll wage, low earners understate the most, and reports scatter around that level with a standard deviation of 0.15 log points (at most 0.19 with 95% confidence; Appendix 7.7). If private employees misreport in the same way, correcting for the scatter alone lowers the average PUT rate slightly, to 7.0% (19.7% at micro firms), and correcting for the understatement as well raises it to 18.5% (34.1%). Two further checks on private employees, at the bottom of the wage distribution where PUT is concentrated, show that they do not overstate either (Appendix 7.7).

Even if respondents do not overstate on average, some may round their wage up by a few soles, and the lower bounds count any positive gap as PUT. To test whether the results are robust to this, I estimate the lower bound again counting only PUT above 15% of the reported wage, and find that at least 6.3% of private formal employees receive PUT (7.4% in 2023), and at least 20.7% at micro firms (26.5%), so the lower bounds are not an artifact of small overstatements (Appendix Table A6).

A last question is whether classical noise could produce the results by itself. Such noise leaves the survey’s mean unchanged but spreads its distribution, which raises the lower bounds, because they count only positive gaps. I build a survey without PUT: each cell’s payroll wages plus mean-zero noise with a standard deviation of 0.15 log points, as among public employees. I then apply the method to it. Noise alone produces a lower bound of 2.9% on the average PUT rate, where the estimate is 7.7%, and of 6.6% at micro firms, where it is 22.0%. In other words, most of each lower bound cannot come from noise: to produce the average PUT rate at micro firms by itself, the noise would need a standard deviation of 0.43, almost three times the 0.15 measured among public employees.

Second, consider sampling noise from finite survey cells. With a finite number of respondents in each cell, the two distributions may differ by chance, and the lower bounds count these chance differences, so sampling noise may push the lower bounds up. The usual confidence bounds, in parentheses in Table 6, do not account for this.

I also report conservative bounds that do, in brackets, following Kline and Tartari (2016).¹⁵ These are also far from zero. In 2022, at least 10.8% of private formal employees receive PUT (29.3% at micro firms), recipients receive at least 8.5% of their reported wage (22.3%), and the average PUT rate is at least 6.7% (19.0%).

Section 4.3 turns these lower bounds into the parameter of the model, the wage-weighted average PUT rate.

4. Optimal Tax Theory with PUT

4.1. Model

I develop a static general-equilibrium model in which PUT arise endogenously in equilibrium, and use it to show how its presence alters the standard optimal labor income tax formula.

The population is normalized to one. Individuals differ in productivity ψ , which for simplicity is assumed to have only mass in $\{0, 1\}$ with exogenous shares s_0 and s_1 . Individuals with $\psi = 0$ do not supply labor and consume only a universal lump-sum transfer T . Individuals with $\psi = 1$ are workers. They may work either formally or in an arrangement that involves underreporting in the form of PUT. Their choice determines labor supply, and how much of their wage is concealed from the government. Firms are competitive, choose labor demand, and take wages as given. The government sets a linear labor income tax on reported earnings, a linear corporate tax on firm profits, and finances the transfer T . The income tax includes both the personal income tax and the payroll taxes. There are no labor market frictions. In equilibrium, wages and allocations are pinned down by market clearing in both the formal and PUT sectors.

Workers Workers are equally productive but differ in how much they value the benefits of formality. I index this heterogeneity by θ , distributed with cdf Q and pdf q . A higher θ means the worker places greater value on accruing those benefits and therefore faces a higher perceived loss from underreporting.

Workers decide whether to work in a formal or a PUT arrangement.¹⁶ For each arrangement, they first solve for optimal hours, and, in PUT, the hidden wage. Then, they pick the arrangement with the higher indirect utility. If a worker works in a formal arrangement, she gets utility $u^F = (1 - \tau)wl + T - v(l)$, where w is the wage, l are the hours of work supplied, τ is the linear personal income tax, T is the universal lump-sum transfer, $(1 - \tau)wl$ is the after-tax income (consumption). v is a strictly increasing function in labor supply. Workers choose l^F that maximizes u^F . The optimization of a worker in the formal arrangement for a given wage w^F yields the following first order condition¹⁷:

$$\max_l \{(1 - \tau)w^F l + T - v(l)\} \quad (2)$$

$$l : \quad (1 - \tau)w^F = v'(l) \quad (3)$$

¹⁵For the extensive margin, the bound of Chernozhukov et al. (2013), which corrects for the upward bias before computing the confidence bound; for the intensive margin and the average PUT rate, a bound from subsampling the survey (Politis et al., 1999). The payroll is a census, so all sampling error sits in the survey; all bounds resample the survey's primary sampling units within strata and redo the reweighting in each draw.

¹⁶I refer to these as 'arrangements' rather than 'submarkets' because they coexist within the same labor market and differ mainly in compliance conditions; wage-setting will nonetheless differ across them.

¹⁷Throughout the paper, l denotes individual hours of labor supplied, and L denotes *aggregate* hours supplied or demanded, integrating across all workers in a given arrangement. The aggregate labor supply is thus a combination of the extensive margin (how many workers select each arrangement, determined by the threshold (θ^*) and the intensive margin (hours per worker, l).

and the corresponding indirect utility function is $V^F(\tau) = (1 - \tau)w^F l^F - v(l^F)$, where l^F solves the FOC.

If a worker chooses a PUT arrangement, she gets utility $u^P = wl - \tau(w - \text{PUT})l + T - v(l) - g(\theta, \text{PUT} \cdot l)$. $\text{PUT} \in [0, w^P]$ is the amount of the wage hidden, or paid under the table. g is a strictly increasing and convex cost function in the hidden wage. The term $g(\theta, \text{PUT} \cdot l)$ is interpreted as the perceived loss of contributory benefits when earnings are not reported. In the PUT arrangement, the personal income tax is only levied on the reported wage which is equivalent to $w - \text{PUT}$. Given w^P , the worker chooses (l, PUT) subject to $0 \leq \text{PUT} \leq w^P$. The optimization of a worker in the PUT arrangement for a given wage w^P yields the following first order conditions:

$$\max_{l, \text{PUT}} \{w^P l - \tau(w^P - \text{PUT})l + T - v(l) - g(\theta, \text{PUT} \cdot l)\} \quad (4)$$

$$l : (1 - \tau)w^P + \tau \text{PUT} = v'(l) + g'_l(\theta, \text{PUT} \cdot l) \quad (5)$$

$$\text{PUT} : \tau = g'_{\text{PUT}}(\theta, \text{PUT} \cdot l) \quad (6)$$

and the corresponding indirect utility function is $V^P(\tau, \theta) = (1 - \tau)w^P l^P + \tau \text{PUT}^* l^P - v(l^P) - g(\theta, \text{PUT}^* l^P)$, where (PUT^*, l^P) solve the FOCs.

A worker chooses the PUT arrangement if $V^P(\tau, \theta) > V^F(\tau)$, which defines a threshold θ^* . Workers choose PUT only if $\theta < \theta^*$. The aggregate hours supplied in the PUT arrangement are $L^{S,P} = s_1 \int_0^{\theta^*} l^P(\tau, \theta) q(\theta) d\theta$, which sums hours over all workers who select PUT. Here s_1 is the share of individuals who are workers. The aggregate hours supplied in the formal arrangement are $L^{S,F} = s_1(1 - Q(\theta^*)) l^F$. In the formal arrangement, hours are the same across workers because productivity and wages are identical. In the PUT arrangement, however, individual hours l^P can vary with θ , since workers take into account their own cost of informality (i.e., the value they place on lost payroll benefits). At a given wage, those with higher θ effectively receive lower compensation and may be willing to supply fewer hours.

Non-workers Individuals who do not work receive a lump-sum transfer T financed by the labor income tax and the corporate tax, so $u^N = T$. Let s_0 denote the share of non-workers in the population; the aggregate transfer to non-workers is $s_0 T$.

Firm There is a representative firm with production function $\phi(\cdot)$ that uses labor and a fixed (short-run) capital stock to produce output. The firm is a price-taker in the product market (output price normalized to 1) and takes wages (w^F, w^P) as given, determined in labor-market equilibrium. The function ϕ is strictly concave, so marginal product of labor falls with scale and the firm earns positive profits. Let total labor be $L = L^F + L^P$, where L^F and L^P are the hours employed in the formal and PUT arrangements, respectively. Pre-tax profits are

$$\pi^{\text{before-tax}} = \phi(L) - w^F L^F - w^P L^P \quad (7)$$

Payroll expenses are deductible only when reported. I assume PUT wages are non-deductible.¹⁸ Let $\bar{\text{PUT}}$ denote the average earnings paid under the table to workers in PUT jobs (taken as given by the firm). Reported

¹⁸If a fraction $d \in [0, 1]$ of hidden payroll is effectively deducted via disguised expenses, $\bar{\text{PUT}}$ is replaced by $(1 - d)\bar{\text{PUT}}$ in the FOC.

profits are

$$\hat{\pi} = \phi(L) - (w^P - \text{P}\bar{\text{U}}\text{T})L^P - w^F L^F \quad (8)$$

so with a linear corporate tax rate t , after-tax profits are

$$\Pi^{\text{after-tax}} = \pi - t\hat{\pi} = (1-t)[\phi(L) - w^F L^F - w^P L^P] - t\text{P}\bar{\text{U}}\text{T} L^P \quad (9)$$

The firm chooses L^F and L^P :

$$\max_{L^F, L^P} (1-t)[\phi(L) - w^F L^F - w^P L^P] - t\text{P}\bar{\text{U}}\text{T} L^P \quad (10)$$

with first-order conditions

$$L^F : (1-t)[\phi'(L) - w^F] = 0 \Rightarrow \phi'(L) = w^F \quad (11)$$

$$L^P : (1-t)[\phi'(L) - w^P] - t\text{P}\bar{\text{U}}\text{T} = 0 \Rightarrow \phi'(L) = w^P + \frac{t}{1-t}\text{P}\bar{\text{U}}\text{T} \quad (12)$$

Combining,

$$w^F = w^P + \frac{t}{1-t}\text{P}\bar{\text{U}}\text{T} \quad (13)$$

I call equation 13, the PUT-formal wage wedge. The firm takes $\text{P}\bar{\text{U}}\text{T}$ as given when choosing labor demand: it depends on workers' hiding decisions and is determined in equilibrium. As workers are equally productive, the marginal product of labor $\phi'(L)$ is the same irrespective of the arrangement. Because only reported payroll is deductible, hiring a PUT hour imposes an extra non-deductible cost of $\frac{t}{1-t}\text{P}\bar{\text{U}}\text{T}$ on the firm. For PUT to exist in equilibrium, the PUT wage must be lower than the formal wage. Otherwise, the firm would have no incentive to hire workers under the table ¹⁹. Given $\text{P}\bar{\text{U}}\text{T}$, the conditions above pin down the firm's labor demands in each arrangement, $L^{D,F}(w^F, t)$ and $L^{D,P}(w^P, t, \text{P}\bar{\text{U}}\text{T})$. After-tax profits at the optimum are $V^\pi(t) = (1-t)[\phi(L^{D,F} + L^{D,P}) - w^F L^{D,F} - w^P L^{D,P}] - t\text{P}\bar{\text{U}}\text{T} L^{D,P}$.

Equilibrium The equilibrium $(w^F, w^P, L^F, L^P, \theta^*)$ satisfies workers' and firm's optimality conditions and simultaneously clears the formal and PUT labor arrangements. The equilibrium conditions are given by

$$L^{D,P}(w^P, t, \text{P}\bar{\text{U}}\text{T}) = L^{S,P}(w^P, \tau, \theta^*) = L^P \quad \text{and} \quad L^{D,F}(w^F, t) = L^{S,F}(w^F, \tau, \theta^*) = L^F,$$

where $L^{S,P}$ and $L^{S,F}$ represent total labor hours supplied by workers, and $L^{D,P}$ and $L^{D,F}$ represent total labor hours demanded by the firm in each arrangement. The market clearing conditions determine the equilibrium wages (w^P, w^F) and the equilibrium allocations (L^P, L^F) .

Aggregate PUT are given by the integral of PUT wages across workers hired in the PUT arrangement:

$$\text{PUT}^{\text{agg}} = s_1 \int_0^{\theta^*} \text{PUT}^*(\tau, \theta; w^P) l^P(\tau, \theta; w^P) dQ(\theta). \quad (14)$$

Thus, equilibrium also determines the threshold θ^* that divides workers across formal and PUT arrangements.

¹⁹This does not imply that the worker's take-home pay is lower in the PUT arrangement. Since a portion of the wage is not subject to taxation, their effective compensation could still exceed the net-of-tax formal wage.

Changes in the personal income tax τ shift labor supply and the threshold θ^* , while changes in the corporate tax t shift firm labor demand directly and, via P $\bar{U}$ T, widen the PUT-formal wage wedge.

Planner The social planner chooses τ (and the transfer T) to maximize a generalized utilitarian social welfare function (SWF). The SWF is given by:

$$\begin{aligned}
SWF = & s_0 \omega_L G(T) \\
& + s_1 \omega_L \int_0^{\theta^*} G\left((1-\tau)w^P l^P + \tau \text{PUT} l^P - v(l^P) - g(\theta, \text{PUT} l^P)\right) dQ(\theta) \\
& + s_1 \omega_L \int_{\theta^*}^{\infty} G\left((1-\tau)w^F l^F - v(l^F)\right) dQ(\theta) \\
& + \omega_\pi G\left((1-t)[\phi(L^P + L^F) - w^P L^P - w^F L^F] + t \text{PUT} L^P\right)
\end{aligned} \tag{15}$$

where G is an increasing and concave function, which, together with the exogenous Pareto weights on individuals ω_L and the firm ω_π summarize the social preferences for redistribution. L^F and L^P are market-clearing labor demands/supplies, and $\text{PUT}^*(\theta)$ denotes optimal PUT per hour for a worker of type θ (so total PUT dollars are $\text{PUT}^*(\theta) l^P(\theta)$). The planner internalizes that $(w^F, w^P, L^F, L^P, \theta^*)$ are equilibrium objects, determined by workers' and firm's FOCs and market clearing. With reported earnings $w^F L^F + (w^P - \text{P}\bar{\text{U}}\text{T})L^P$ and reported profits $\hat{\pi} = \phi(L^F + L^P) - (w^P - \text{P}\bar{\text{U}}\text{T})L^P - w^F L^F$, the balanced-budget condition is

$$T = \tau \left[w^F L^F + (w^P - \text{P}\bar{\text{U}}\text{T})L^P \right] + t \hat{\pi} \tag{16}$$

Let λ be the multiplier on the government budget constraint. The average social welfare weight of non-workers, workers in PUT arrangement, workers in formal arrangement, and firms, are defined respectively as:

$$\begin{aligned}
g_N &= \frac{\omega_L G'(T)}{s_0 \lambda}, & g_L^P &= \frac{\omega_L \int_0^{\theta^*} G'(V^P(\theta)) dQ(\theta)}{s_1 Q(\theta^*) \lambda} \\
g_L^F &= \frac{\omega_L \int_{\theta^*}^{\infty} G'(V^F) dQ(\theta)}{s_1 (1 - Q(\theta^*)) \lambda}, & g_\pi &= \frac{\omega_\pi G'(V^\pi)}{\lambda}
\end{aligned} \tag{17}$$

The welfare weights represent the social value of the marginal utility of consumption normalized by the social cost of raising public funds, thus measuring the social value of redistributing one dollar across a group of individuals. At the optimum, the planner is indifferent between giving one more dollar to an individual in group i or having g_i more dollars of public funds.

4.2. Optimal Income Tax

Before deriving the optimal income tax, I define the elasticities (all with respect to the log net-of-tax rate):

$$e_1^i = \frac{\partial \log L^i}{\partial \log(1-\tau)}, \quad i \in \{P, F\}; \quad e_2 = \frac{\partial \log \overline{\text{PUT}}}{\partial \log(1-\tau)} \tag{18}$$

e_1 is the elasticity of labor supply and e_2 is the elasticity of average PUT with respect to the net-of-tax rate (intensive margin of PUT evasion). These are general-equilibrium elasticities that include all quantity adjustments in their respective arrangements.

Two remarks about elasticities. First, e_1^i aggregates all labor-supply margins: a change in $1 - \tau$ shifts both the number of workers in arrangement i (selection) and their hours (intensive response). I do not separate these components. Second, the sign of e_1^F is positive. The sign of e_1^P is a priori ambiguous. When $1 - \tau$ increases, workers supply more hours in both arrangements due to the Frisch elasticity of labor supply, which pushes e_1^P in the positive direction. However, a higher net-of-tax wage also makes hiding less attractive, so fewer workers choose the PUT arrangement and L^P declines, pulling e_1^P down. I assume that the Frisch elasticity is smaller, so the net effect is negative, implying $e_1^P < 0$.

The wage elasticities with respect to the net-of-tax rate are defined as follows²⁰:

$$\eta^P = \frac{\partial \log w^P}{\partial \log(1 - \tau)}, \quad \eta^F = \frac{\partial \log w^F}{\partial \log(1 - \tau)} \quad (19)$$

Because a higher τ pushes workers toward PUT, formal wages rise and PUT wages fall. Since elasticities are with respect to $\log(1 - \tau)$, under the same assumptions as for labor-supply elasticities, this implies $\eta^F < 0$ and $\eta^P > 0$.

Aggregate income in arrangement i is $Z^i = w^i L^i$. Aggregate reported income is

$$\hat{Z} = \underbrace{w^F L^F}_{\hat{Z}^F} + \underbrace{(w^P L^P - \text{PUT}^{\text{agg}})}_{\hat{Z}^P}, \quad (20)$$

and define the shares (of the reported base)

$$\alpha^F = \frac{Z^F}{\hat{Z}}, \quad \alpha^P = \frac{Z^P}{\hat{Z}}, \quad \gamma = \frac{\text{PUT}^{\text{agg}}}{\hat{Z}}, \quad \text{so} \quad \alpha^F + \alpha^P - \gamma = 1 \quad (21)$$

I refer to γ as the wage-weighted average PUT rate. Using the model, I derive the conditions for an optimal personal income tax in this economy. The Appendix shows the full derivation. From the first-order conditions and using the envelope theorem for the workers and the firm maximization, I get the following expression for the optimal labor income tax:

$$\tau^* = \frac{1 - \bar{g} - \Omega - t \gamma \left((1 - g_\pi) e_2 \right)}{1 - \bar{g} - \Omega + \underbrace{\alpha^P (e_1^P + \eta^P) + \alpha^F (e_1^F + \eta^F) - \gamma (e_1^P + e_2)}_{\text{ETI}}} \quad (22)$$

$\bar{g} = g^P \alpha^P + g^F \alpha^F$, where g_L^P and g_L^F are the average social marginal welfare weights on PUT and formal workers, respectively. g_π is the weight on firm profits. The term $t \gamma (1 - g_\pi) e_2$ captures the corporate–evasion interaction: changes in τ change PUT, and because PUT payroll is non-deductible, this shifts the CIT base; $(1 - g_\pi)$ converts that into social value.

Equation (22) is the classical efficiency–equity tax formula with evasion and a fiscal externality, as in Piketty

²⁰These are also general-equilibrium elasticities: η^i captures all equilibrium adjustments in wages in arrangement i when the net-of-tax rate changes.

et al. (2014). It balances redistributive gains (numerator) against efficiency costs (denominator), with the novelty that both are shaped by general-equilibrium responses that are functions of the corporate tax rate. In the numerator, a higher welfare weight on workers ($\bar{g}$) lowers the optimal tax rate, as in the standard case. The new element is the positive fiscal externality: PUT wages increase taxable profits and therefore corporate tax revenue. This makes the corporate tax rate t enter directly, with the effect scaled by the wage-weighted average PUT rate (γ), the elasticity of evasion ($e_2 < 0$), and the welfare weight on firms (g_π). The higher the welfare weight on firms, the smaller the social value of this externality.

Ω captures the welfare effect of wage adjustments induced by τ :

$$\Omega = \alpha^F \left(\frac{1-t}{1-\tau} g_\pi - g_L^F \right) \eta^F + \alpha^P \left(\frac{1-t}{1-\tau} g_\pi - g_L^P \right) \eta^P \quad (23)$$

When w^i moves by dw^i in arrangement $i \in \{F, P\}$, workers gain $(1-\tau)L^i dw^i$ while the firm loses $(1-t)L^i dw^i$. If the planner values workers more than the firm after tax (i.e. $g_L^i > \frac{1-t}{1-\tau} g_\pi$), the formal term is positive while the PUT term is negative. Hence $\Omega > 0$ when the formal-side response dominates (decreasing τ^*), and $\Omega < 0$ when the PUT-side response dominates (increasing τ^*).

Define the ETI as the log elasticity of aggregate reported income $\hat{Z}$ with respect to the net-of-tax rate $1-\tau$. A small increase in $1-\tau$ changes $\hat{Z}$ through: (i) labor supply and wages in each arrangement, and (ii) the amount of income hidden under the table. Aggregating these channels yields:

$$\text{ETI} = \alpha^P(e_1^P + \eta^P) + \alpha^F(e_1^F + \eta^F) - \gamma(e_1^P + e_2) \quad (24)$$

where the first two terms capture formal and PUT income responses and the last term captures the effect of moving income under the table.

The ETI combines labor-supply elasticities e_1^i , wage elasticities η^i , and the PUT evasion elasticity e_2 . These are general equilibrium elasticities and are weighted by income shares and the wage-weighted average PUT rate. Equation (22) shows that the ETI captures all the efficiency costs associated with raising the income tax rate. In this sense, the ETI is a sufficient statistic of this model. Once the ETI is known, the welfare effect of changing $(1-\tau)$ can be computed without specifying the full microstructure of preferences or informality costs. The difference is that the ETI depends on structural parameters related to PUT behavior between workers and firms, as well as wage effects that vary with the corporate tax rate.

Special Case. If wages do not respond ($\eta^P = \eta^F = 0$) and the corporate tax is zero ($t = 0$), (22) reduces to

$$\tau^* = \frac{1 - \bar{g}}{1 - \bar{g} + \underbrace{\alpha^P e_1^P + \alpha^F e_1^F - \gamma(e_1^P + e_2)}_{\text{ETI}}}, \quad (25)$$

which is identical to the well-known standard optimal linear tax rate in Mirrleesian frameworks (Piketty and Saez, 2013). Appendix 8.1 shows that deriving (22) with perturbation methods—considering a marginal increase in τ —yields the same result.

ETI as a function of the corporate tax rate t The corporate tax affects both the equilibrium allocation between formal and PUT arrangements and the relevant elasticities. To show the mechanisms, I differentiate the ETI with respect to t and denote derivatives as $x' = \partial x / \partial t$:

$$\frac{d\text{ETI}}{dt} = \underbrace{\alpha^{P'}(e_1^P + \eta^P) + \alpha^{F'}(e_1^F + \eta^F) - \gamma'(e_1^P + e_2)}_{\text{Composition}} \quad (26)$$

$$+ \underbrace{\alpha^P(e_1^{P'} + \eta^{P'}) + \alpha^F(e_1^{F'} + \eta^{F'}) - \gamma(e_1^{P'} + e_2')}_{\text{Behavioral}} < 0 \quad (27)$$

Appendix 8.2 shows the proof of $\frac{d\text{ETI}}{dt} < 0$. Here I develop the intuition. A higher corporate tax lowers the ETI through two forces. First, it shifts the composition of the labor force: fewer workers choose the PUT arrangement. A higher t raises the effective cost of PUT labor (since hidden wages are not deductible), lowering w^P relative to w^F and shifting employment toward the formal sector. Thus, for a given informality cost, the PUT arrangement is less attractive to workers, making the share of workers in PUT fall ($\alpha^F \uparrow$, $\alpha^P \downarrow$, $\gamma \downarrow$). As a result, when the income tax changes, there are fewer workers in the PUT arrangement who can adjust their level of evasion, making the ETI less responsive.

Second, a higher corporate tax alters how workers respond to changes in the income tax, which directly affects the ETI. It raises the effective cost of hiring PUT workers and of paying a dollar under the table. As a result, firms are less willing to offer these contracts, and workers become less able to shift into the PUT arrangement when the income tax rate changes. Since evasion requires agreement from both sides of the market, the behavioral elasticities related to concealment fall ($e_1^P \downarrow$, $e_2 \downarrow$). This makes reported income less responsive to income tax changes, and therefore lowers the ETI. Together, a higher t both shrinks the size of the PUT sector and reduces its elasticity, making reported income less responsive to changes in the income tax (ETI $\downarrow$).

Mapping t - to τ -elasticities. A key feature of the model is that all relevant behavioral margins—labor supply in each arrangement, hidden wages, and equilibrium wages—are jointly determined through a single surplus condition. Define the employer–employee surplus wedge as

$$S = \tau - \frac{t}{1-t} \quad (28)$$

where the first term captures the personal income tax burden and the second term reflects the effective non-deductibility of hidden pay.

Totally differentiating the equilibrium system shows that first-order responses of all endogenous variables are proportional to changes in dS . Appendix 8.3 shows the algebra. A change in the corporate tax t and a change in the personal tax τ affect the economy only through their joint impact on S :

$$dS = d\tau - \frac{1}{(1-t)^2} dt \quad (29)$$

$$(1-\tau) d\log(1-\tau) = \frac{1}{1-t} d\log(1-t) \quad (30)$$

In other words, a one-percent increase in firms' deductibility $(1-t)$ generates the same change in the surplus as a $(1-\tau)(1-t)$ -percent increase in workers' net-of-tax rate $(1-\tau)$. Thus t -elasticities can be directly mapped

into τ -elasticities as

$$e^{1-\tau} = (1-\tau)(1-t) e^{1-t} \quad (31)$$

This mapping shows that t -elasticities are also sufficient statistics for the efficiency costs of taxation, once scaled by $1/[(1-\tau)(1-t)]$. This gives the planner an alternative way of estimating the ETI even in the absence of income tax reforms: observed responses to corporate-tax reforms contain the same information about efficiency costs as income tax reforms, after applying this conversion.

4.3. Measuring γ

The model has one parameter for PUT, $\gamma = \text{PUT}/\hat{Z}$, total PUT over total reported labor income, with PUT non-negative. Its empirical counterpart is the average PUT rate of Section 3.3, weighted by reported wages instead of by workers: the *wage-weighted average PUT rate*. For any pairing, the average PUT rate gives every worker the same weight, $\rho = E[(\text{PUT}/\hat{w})^+]$. Weighting each worker by the reported wage instead turns the same average into total positive PUT over the total reported wage bill:

$$\gamma = \frac{\sum_i \hat{w}_i (\text{PUT}_i/\hat{w}_i)^+}{\sum_i \hat{w}_i} = \frac{\sum_i \text{PUT}_i^+}{\sum_i \hat{w}_i}.$$

Workers whose true wage is at or below the reported wage count as zero, consistent with PUT being non-negative in the model. Like the average PUT rate, its least value over all pairings is attained by rank invariance, which pairs the u -th percentile of reported wages with the u -th percentile of true wages in each cell:

$$\gamma^+ = \frac{\sum_c n_c \int_0^1 (F_{w,c}^{-1}(u) - F_{\hat{w},c}^{-1}(u))^+ du}{\sum_c n_c \bar{\hat{w}}_c},$$

where n_c is the number of payroll workers in cell c and $\bar{\hat{w}}_c$ their mean reported wage. So γ^+ is the lower bound on the wage-weighted average PUT rate. Like every estimate in Section 3, γ^+ refers to private formal employees inside the estimation window, and the model uses the same window.

Table 7 reports γ^+ . PUT is at least 6.3% of reported labor income in the economy and 22.9% at micro firms in 2022 (6.5% and 27.2% in 2023). With ENAHO, which covers 2020–2023, the lower bound lies between 4.8% and 6.4% in every year, and between 18.7% and 20.8% at micro firms. These values are below EPEN’s in the two years both surveys cover, especially at micro firms.

5. ETI Estimates

In this section, I take the theoretical model to the data. As shown in the previous section, the ETI remains a sufficient statistic in an economy with PUT, but it becomes a negative function of the corporate tax rate. This section estimates the ETI and empirically tests its relationship with the corporate tax rate.

5.1. Identification

To estimate the ETI, I use a difference-in-differences (DiD) design and an event-study framework. The identifying variation comes from the 2021 and 2023 changes to Peru’s Agricultural Regime.

Table 7: Wage-weighted average PUT rate, γ^+ : lower bound over all pairings (%)

	2020	2021	2022		2023	
	ENAH0	ENAH0	ENAH0	EPEN	ENAH0	EPEN
All	6.4	5.0	5.8	6.3	4.8	6.5
	(4.8)	(4.0)	(4.6)	(5.5)	(3.5)	(5.7)
	[4.2]	[3.1]	[4.1]	[5.2]	[3.2]	[5.6]
1–10	20.8	20.0	19.9	22.9	18.7	27.2
	(15.2)	(15.8)	(16.4)	(19.2)	(14.1)	(24.4)
	[13.6]	[15.2]	[14.3]	[19.4]	[13.9]	[24.4]
11–100	3.5	2.2	3.5	3.4	2.0	2.3
	(1.5)	(0.8)	(2.2)	(2.3)	(0.8)	(1.6)
	[0.1]	[0.0]	[1.2]	[2.1]	[0.5]	[1.3]
101–500	3.5	1.4	3.1	2.2	1.5	0.8
	(1.4)	(0.0)	(0.8)	(1.2)	(0.0)	(0.3)
	[0.0]	[0.0]	[1.0]	[1.0]	[0.0]	[0.1]
More than 500	3.9	2.6	3.3	4.0	2.5	3.7
	(1.7)	(0.9)	(1.8)	(2.9)	(0.5)	(2.5)
	[1.1]	[0.1]	[1.0]	[2.4]	[0.3]	[2.3]
Agriculture	3.6	10.3	13.1	15.0	13.5	11.0
	(1.6)	(8.2)	(11.1)	(13.1)	(11.0)	(9.6)
	[1.2]	[7.7]	[9.9]	[12.6]	[10.7]	[8.5]
Mining	9.4	8.8	5.6	7.0	6.6	6.7
	(5.9)	(4.8)	(3.1)	(4.1)	(2.6)	(4.6)
	[4.8]	[3.5]	[0.0]	[3.6]	[0.7]	[3.2]
Manufacturing	5.4	3.8	2.9	4.2	4.0	5.0
	(3.0)	(1.6)	(0.7)	(1.9)	(0.9)	(3.7)
	[1.7]	[0.4]	[0.0]	[2.3]	[0.1]	[3.5]
Construction	19.6	7.4	21.5	12.5	10.6	10.7
	(12.6)	(3.3)	(15.1)	(9.8)	(5.4)	(8.2)
	[8.4]	[1.7]	[13.4]	[9.5]	[3.6]	[7.6]
Commerce	4.2	5.4	4.4	7.4	4.5	6.9
	(1.6)	(3.3)	(2.5)	(4.6)	(2.4)	(5.1)
	[0.4]	[2.1]	[1.2]	[4.8]	[1.6]	[5.0]
Services	5.2	3.7	3.2	4.3	3.3	5.8
	(3.0)	(2.1)	(1.8)	(3.4)	(1.6)	(4.5)
	[2.1]	[1.5]	[1.8]	[2.9]	[1.5]	[4.7]

Notes: γ^+ : wage-weighted average PUT rate, positive PUT in soles over the reported wage bill, the least value over all pairings (attained by rank invariance), counting negative gaps as zero. One-sided 95% lower confidence bounds: in parentheses, the estimate minus 1.645 bootstrap standard errors (bounds below zero are reported as zero); in brackets, subsampling. Formal employees: health insurance paid by the employer, in both surveys. Private formal employees in the estimation window. Cells: firm size (1–10, 11–100, 101–500, more than 500 workers) by sector (agriculture, mining, manufacturing, construction, commerce, services); within cells, survey weights are reweighted to the payroll's shares by age group, sex and Lima. Group statistics average cells weighted by payroll workers.

Since 2001, *eligible* workers in agricultural firms could be hired under a special agricultural regime in which they were subject to a 4% healthcare (EsSalud) contribution, compared to 9% under the general regime. Eligible workers include those engaged in farming, livestock, and agro-industrial activities carried out in the field. However, administrative and technical support staff who do not perform their duties primarily in the firm’s fields are excluded and must be hired under the general regime. The corporate income tax rate for all agricultural firms was also reduced to 15%, compared to 29.5% under the general regime. This Agricultural Regime was set to expire in December 2021.²¹

In 2019, health authorities repeatedly noted that the cost per worker hired under the agricultural regime far exceeded their contributions and called for an increase.²² In December 2020, Congress passed a reform that increased payroll tax rates (EsSalud contributions) for workers in agricultural firms hired under the Agricultural Regime, with rates differentiated by firm size. Firms with fewer than 100 workers saw their healthcare contribution rate rise to 6% starting in 2021, while firms with 100 or more workers faced a gradual increase: 7% in 2021–2022 and 8% from 2023 onward. The corporate tax rate remained unchanged during 2021–2022 but was raised to 20% for large firms starting in 2023. Table 8 summarizes these changes.

Table 8: Marginal Tax Rates

Year	Agricultural Regime (AgR)				General Regime (GR)	
	Healthcare		Corporate Tax		Healthcare	Corporate Tax
	< 100	≥ 100	< 100	≥ 100	All	All
	workers	workers	workers	workers	(5)	(6)
	(1)	(2)	(3)	(4)		
2020	4%	4%	15%	15%	9%	29.5%
2021	6%	7%	15%	15%	9%	29.5%
2022	6%	7%	15%	15%	9%	29.5%
2023	6%	8%	15%	20%	9%	29.5%

As in the theoretical model, I treat the effective tax on labor income as the sum of the personal income tax and the payroll tax $\tau = \tau^{\text{PIT}} + \tau^{\text{payroll}}$. Healthcare (EsSalud) coverage and service entitlements are not a function of the employer contribution rate at the margin; workers receive the same benefits irrespective of whether $\tau^{\text{payroll}} = 4\%, 6\%, 7\%, 8\%$. Hence the contribution behaves like a tax on labor rather than a priced benefit. Throughout, I therefore interpret changes in the payroll tax as changes in τ .

To quantify how the mechanical tax changes (driven by changes in the tax laws) affect reported income, I estimate a continuous difference-in-differences model that exploits two sources of intensity variation within the agricultural sector: (i) whether a worker is hired under the special agricultural regime or the general regime (I call this the ‘regime’ variable), and (ii) whether the firm has fewer or more than 100 employees (I call this the ‘firm-size’ variable). Restricting to agriculture rules out cross-sector productivity differences.

²¹These benefits were initially set to expire on December 31, 2010, but their validity was later extended until December 31, 2021.

²²In December 2020, EsSalud’s president reported that, for every S/100 contributed by agricultural firms, workers consumed S/262 in services—meaning healthcare costs were 2.6 times their contributions. These workers were subject to a 4% contribution rate, rather than the standard 9% for other sectors (Agraria.pe, 2020).

Following Kleven and Schultz (2014), I first estimate the following specification on 2020–2022:

$$\log \hat{z}_{ijt} = \alpha + \varepsilon \log(1 - \tau_{jt}) + X_{ijt}\gamma + \delta_j + \delta_t + \nu_{ijt}. \quad (32)$$

Here, $\hat{z}_{ijt}$ is reported labor income of worker i in firm-size $\times$ regime cell j and year t , and τ_{jt} is the statutory income-tax rate for cell j and year t . In this setting the statutory rate τ_{jt} is flat within a cell $\times$ year, so $\log(1 - \tau_{jt})$ does not depend on individual income $\hat{z}_{ijt}$. Unlike in nonlinear schedules, there is no virtual-income term and no need for simulated IV; the regressor is mechanically determined by law. Identification comes from continuous DiD variation in the dose $\log(1 - \tau_{jt})$ across regime $\times$ size cells over time.

I include group fixed effects δ_j (firm-size $\times$ regime) and month-year fixed effects δ_t , plus regional (department) fixed effects. $\varepsilon = \partial \ln \hat{z} / \partial \ln(1 - \tau)$ is the ETI: a 1% increase in $1 - \tau$ is associated with an $\varepsilon\%$ increase in reported income. The 2020–2022 estimates capture the elasticity of taxable labor income when there are no changes in the corporate tax. I then re-estimate the same specification on 2022–2023, restricting the sample to large firms:

large firms in the AgR are treated and large firms in the GR are controls. ε still measures the ETI but in a setting where the corporate tax also increases. In 2023, large firms in the agricultural regime faced a 1 percentage point increase in the income tax and a concurrent increase in the corporate tax from 15% to 20%. This setting lets me estimate the ETI off a 1 percentage point change in the net-of-income-tax rate while corporate tax also moved. Large firms in the general regime saw no change in either tax. Under the assumption that the ETI is stable over this short window, any difference from the 2020–2022 estimate is informative about how the concurrent corporate-tax change interacts with the income-tax response. Under the ‘surplus-wedge’ logic of the model, the concurrent corporate-tax increase should attenuate the measured response to labor income-tax changes.

5.2. Results

Table 9 shows the results. Column (1) reports the ETI for 2020–2022. Firms in the Agricultural Regime (AgR) are treated with the change in the net-of-tax rate $1 - \tau$, while firms in the General Regime (GR) operating in agriculture serve as controls because their income-tax schedule does not change over this window. The ETI is identified from within-unit changes for AgR between 2021–2022 relative to the pre period in 2020, net of the change for GR over the same calendar months. Estimates imply that a 1% *decrease* in the net-of-tax rate is associated with about a 2.3% *decrease* in reported labor income (implied ETI ≈ 2.3). This is the pooled effect across small and large firms. This result is robust to the inclusion of different controls and fixed effects. Columns (2) and (3) split the sample by size, comparing large AgR firms with large GR firms and small AgR firms with small GR firms; the elasticity is larger for large firms.

Column (4) focuses on 2022–2023 where large firms are the only treated ones. Large AgR firms are treated in 2023, while large GR firms face no change and act as controls. With group, month-year, and department fixed effects, the coefficient on $\ln(1 - \tau)$ is identified by the within-unit change for large AgR firms in 2023 relative to 2022, net of the change for large GR firms in the same months. In this case the estimates are smaller and barely statistically significant. This suggests that the 1 percentage point income-tax increase, which coincided with an increase in the corporate tax rate, did not measurably change reported labor income over this short window. Under the assumption that the ETI is stable across this period, the lack of a detectable response to the 2023 income-tax change is consistent with the corporate tax offsetting part of the income-tax effect.

Table 9: ETI Estimates

	Dep. Var.: Log Reported Labor Income			
	2020–2022			2022–2023
	All	Large	Small	Large
Treated firms:	(1)	(2)	(3)	(4)
$\ln(1 - \tau_{jt})$	2.274*** (0.410)	2.614*** (0.684)	1.620*** (0.254)	0.748* (0.337)
Treatment	AgR	Large AgR	Small AgR	Large AgR
Control Firms	GR	Large GR	Small GR	Large GR
Time FE (month-year)	Yes	Yes	Yes	Yes
Group FE (firm size $\times$ regime)	Yes	Yes	Yes	Yes
Region FE	Yes	Yes	Yes	Yes
Worker controls [†]	Yes	Yes	Yes	Yes
Observations	10,003,142	8,774,570	1,228,572	4,051,641
R^2	0.223	0.216	0.230	0.116

Notes: AgR is Agricultural Regime and GR is General Regime. Dependent variable is $\ln(\hat{z}_{ijt})$, reported labor income. Columns (1)–(3) use 2020–2022, when the corporate tax does not change. Column (4) uses 2022–2023, when the corporate tax rises for large firms in the agricultural regime. Standard errors (parentheses) are clustered at the firm-size $\times$ regime level. *** $p < 0.01$, ** $p < 0.05$, * $p < 0.10$. [†] Controls: gender, education, age, occupation dummies, pension-regime dummies, and firm-size dummies.

ETIs of around 2 may seem large compared to ETIs in developed economies, where estimates usually fall between 0.1 and 0.4 for labor income (Chetty, 2012; Saez et al., 2012). These imply that labor supply responses to changes to the net-of-tax rate are small. But it is well established that the ETI is not a structural parameter pinned down only by preferences or technologies. It also reflects the design of the tax system and the scope for avoidance and evasion (Slemrod and Kopczuk, 2002). In developing countries, where informal sectors are large and enforcement is weaker, higher ETIs are expected. Although there are fewer studies in these contexts, existing work has documented ETIs in the range of 2–5.²³ These findings line up closely with my estimates.

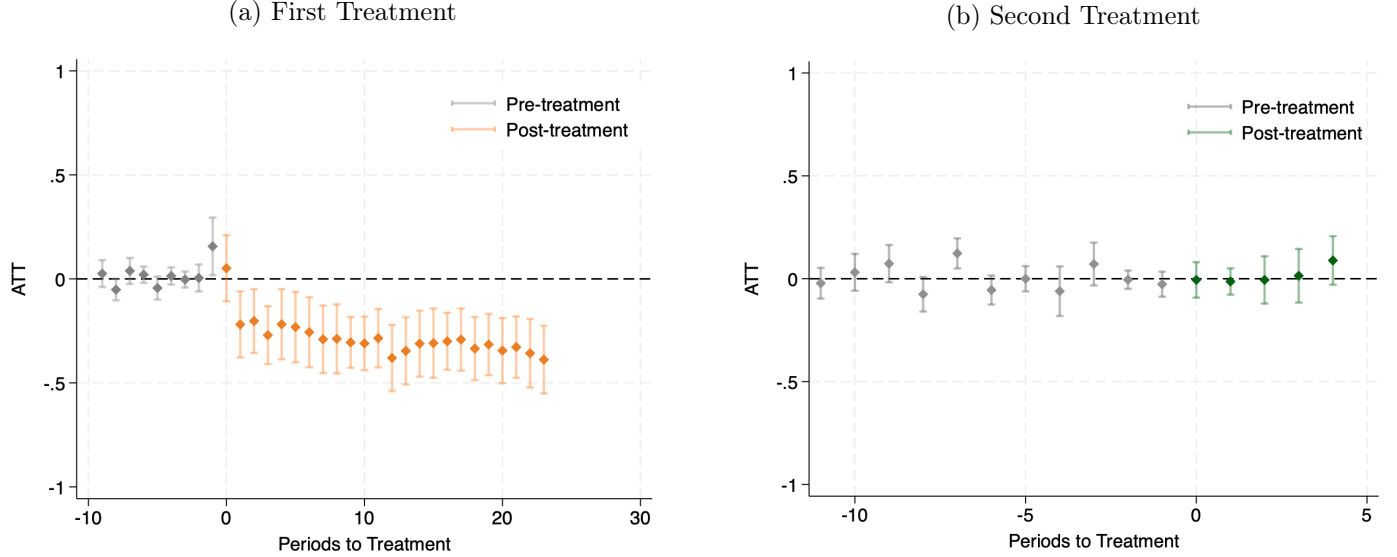
Besides the regression, I use event studies to do two things: (i) test for parallel trends in the pre-period and (ii) see whether there is a discrete jump right when the policy takes effect. The coefficients plot ATT at each event month relative to the month just before treatment (December the previous year). These figures are complementary. These do not replace the ETI regressions, since the elasticity is identified from the slope with respect to $\ln(1 - \tau)$. The Appendix shows the details of the event studies.

Figure 3 plots dynamic DiD estimates around each reform. Panel A compares AgR firms to GR firms around the 2021 change. Pre-treatment coefficients are centered around zero, which is consistent with parallel trends. After the reform, the path turns negative and stays there: the ATT settles around -0.3 to -0.4 log points within the first year and remains persistently below zero. This lines up with the ETI estimates for 2020-2022 shown in

²³Bachas and Soto (2021) estimate elasticities of taxable profits of 3–5 in Costa Rica. Waseem (2018) finds ETIs of about 2–3 in Pakistan using a large PIT reform. W Yan and Gao (2023) estimate income elasticities above 2 for a payroll tax reform in China.

Column (1) of Table 9. Panel B restricts to the AgR firms and compares large AgR firms to small AgR firms around the 2023 change. Pre-period coefficients are close to zero, and post-treatment estimates are small and imprecise, centered near zero. That pattern matches the ETI estimates for AgR firms in 2022–2023 in Column (4) of Table 9, where the point estimate is modest and not precise.

Figure 3: ETI Estimates: Event Studies



I use the same windowing as in the regressions of Table 9, and the bins are defined relative to the month before treatment. GR firms (control units) never activate in the event dummies; they only help pin down the time effects in Panel A.

Taken together, the 2020–2022 estimates and the flat response after the 2023 reform are consistent with the model’s prediction that the elasticity of taxable income is a decreasing function of the corporate tax rate: ETIs are high when the corporate tax is low and attenuate sharply when the corporate tax increases.

5.3. Implications for the Optimal Tax

In this subsection, I use the ETI estimates to compute the optimal labor income tax implied by the model. I evaluate the optimal tax formula (22) under two simplifications. First, I set wage effects to zero ($\eta^P = \eta^F = 0$, so $\Omega = 0$). Second, because the ETI equals $e_1 - \gamma e_2$ (Appendix 8.1), I write the fiscal externality in terms of the ETI and the labor-supply elasticity e_1 , so I do not need a separate estimate of the PUT elasticity e_2 . The formula becomes

$$\tau^* = \frac{1 - \bar{g} + t(1 - g_\pi)(\text{ETI} - e_1)}{1 - \bar{g} + \text{ETI}}. \quad (33)$$

The ETI comes from Table 9. I take $e_1 = 0.2$, which is within the range in Chetty (2012), and set $\bar{g} = 0.6$ and $g_\pi = 0$.

Table 10 reports the optimal tax rate in four cases. In the first case, evasion is a decision of workers alone, as in standard models. The corporate tax plays no role, so there is no fiscal externality, and I use the ETI estimated when only the labor income tax changed, 2.3. The optimal tax rate is 15%. In the second case, there

is PUT and the corporate tax is 15%, the rate agricultural firms faced in 2020–2022. The ETI is the same, but the fiscal externality raises the optimal tax rate to 26%. In the third case, there is PUT and the corporate tax is 20%, as for large agricultural firms in 2023. The ETI falls to 0.75, and the optimal tax rate rises from 26% to 44%. Most of this increase comes from the lower ETI. To see this, suppose the corporate tax rose to 20% but workers kept responding as much as before, with an ETI of 2.3. Only the fiscal externality would change, and the optimal tax rate would rise only from 26% to 30%. Both channels of the model therefore raise the optimal tax rate.

Table 10: Optimal labor income tax in four cases (%)

	Corporate tax	ETI	Fiscal externality	τ^*
Workers alone	–	2.3	No	14.8
PUT	15%	2.3	Yes	26.5
PUT	20%	0.75	Yes	44.3
Reported wages are true	–	0.2	No	66.7

Notes: Equation (33) with $\bar{g} = 0.6$, $g_\pi = 0$ and $e_1 = 0.2$. ETI: estimates in Table 9, columns (1) and (4). Workers alone: evasion is a decision of workers alone, so there is no fiscal externality in the numerator. Reported wages are true: the government takes reported wages as true in an economy with PUT, so the ETI it perceives is the labor-supply elasticity e_1 and there is no fiscal externality. Appendix Table MA1 reports other values of $\bar{g}$, g_π and e_1 .

The fourth case shows what happens if the government misreads underreporting. If it assumes there is no PUT and treats underreporting as a decision of workers alone, it sets the tax too low, at 15% instead of 26 to 44%. If it instead takes reported wages as true in an economy with PUT, the only response to taxes it sees is labor supply. The ETI it perceives is then the labor-supply elasticity, 0.2, and it sets the tax too high, at 67%.

Given that this paper does not estimate the welfare weights or the labor-supply elasticity, I also try other values. For every combination of $\bar{g} \in \{0.5, 0.6, 0.7\}$, $e_1 \in \{0, 0.2, 0.4\}$ and $g_\pi \in \{0, 0.25\}$, the optimal tax rate is lowest when evasion is a decision of workers alone and highest when reported wages are taken as true (Appendix Table MA1). As the model predicts, the optimal labor income tax rises with the corporate tax.

6. Concluding Remarks

This paper studies payments under the table (PUT), a form of wage underreporting in which firms and workers collude to report only part of the wage to the tax and social security authorities and pay the rest off the books. This type of wage underreporting has been documented in the literature, mostly using surveys, and is especially prevalent in Latin America and Eastern Europe. Yet its implications for tax policy design remain largely unexplored.

The paper makes two contributions to the study of PUT, one in measurement and one in optimal tax design. On the measurement side, I compare administrative payroll records with household surveys, data that most governments already collect, without linking them. Within cells of comparable workers, self-reported wages exceed third-party reported wages by 5.5% at the mean and 8.4% at the median, and by far more at micro firms. Because the two sources cannot be linked, I use optimal transport to compute the smallest extensive and intensive margins of PUT consistent with both wage distributions: at least 13.2% of private formal employees

receive PUT, and those who do are paid at least 9.7% of their reported wage under the table. A government that wants to assess the extent of PUT could apply this approach directly.

On the tax design side, I develop a general equilibrium model of optimal income taxation in an economy where there is also a corporate tax. The key result is that because PUT cannot be deducted from firms' taxable profits, the response of workers to changes in the income tax (the ETI) depends negatively on the corporate tax rate. The ETI is lower when the corporate tax is higher, which allows governments to set a higher optimal income tax rate than they would in a setting with only worker-side evasion. To test this mechanism in the data, I leverage a tax reform in Peru that affected the contracts of *some* agricultural workers and unfolded in two stages: first, only the income tax increased; second, both the income and corporate taxes increased. The reform applied only to field workers hired under the Agricultural Regime (treated workers), while administrative workers in the same firms remained under the General Regime, whose tax rates did not change (control workers). Using the administrative dataset, I estimate the ETI for all agricultural workers and show that it is higher in the first stage, when the corporate tax did not change. Plugging these estimates into the optimal tax formula, the optimal labor income tax rises from 26% to 44% as the corporate tax rises from 15% to 20%, against 15% if evasion were a decision of workers alone and 67% if reported wages were taken as true.

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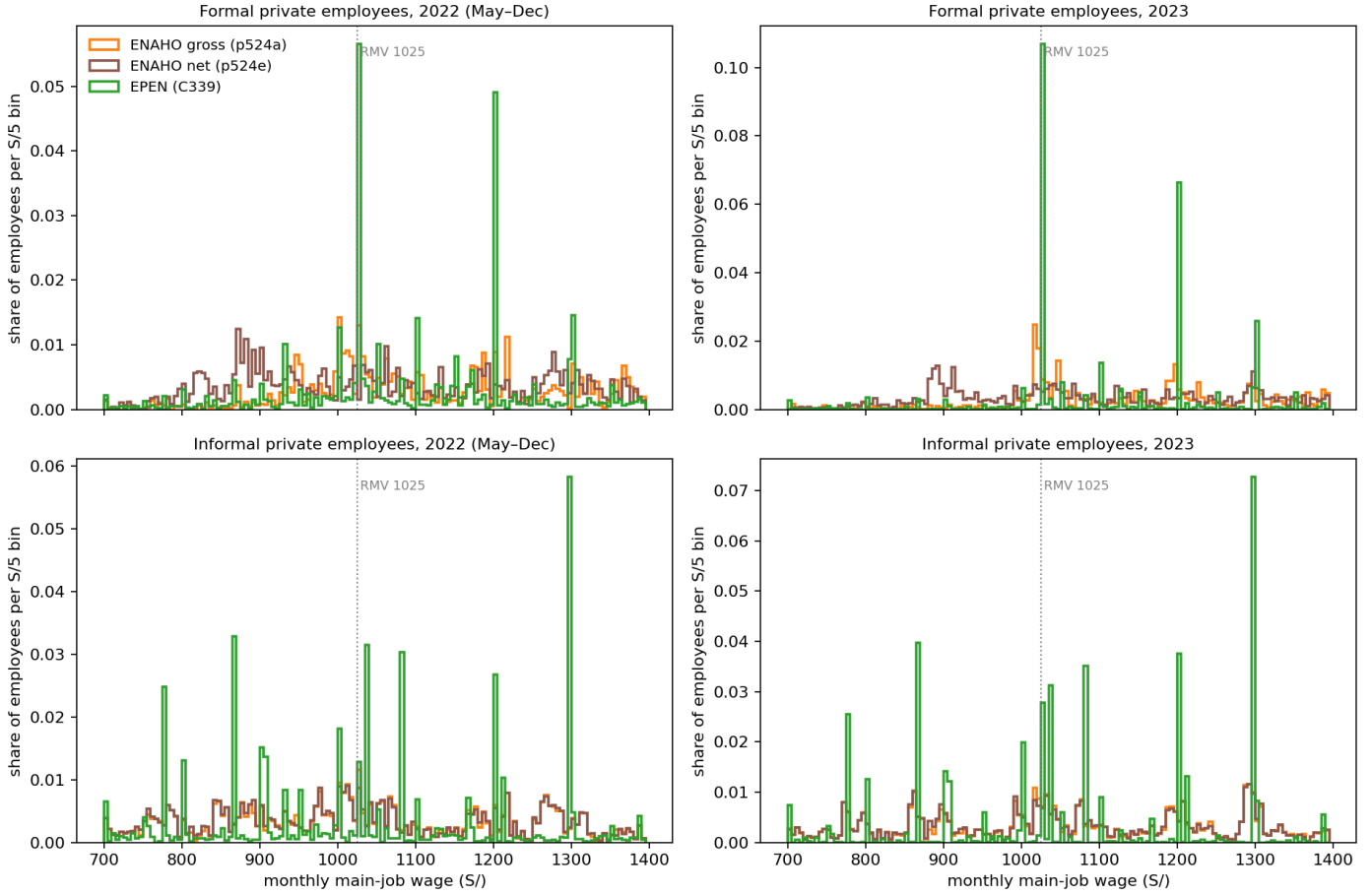
7. Appendix to Section 3

7.1. Data

Sources. Besides the gross wage, the payroll records each worker’s pension and health-insurance regime and the employer’s labor regime; it has no information on firms’ sales or profits. It has been collected electronically since 2010 and is publicly available since 2020. Both surveys are nationally representative, urban and rural, in all 25 regions. In both, I use only the respondent’s main job: the wage is the gross monthly income from the main job, and the sector, firm size and type of employer are those of the same job. Secondary jobs are not used. EPEN interviews a rotating panel of dwellings every month; the annual file stacks the monthly interviews, and its annual weights account for dwellings interviewed more than once. It asks for total monthly income from the main job, including overtime and bonuses. ENAHO’s employment and income module (Module 500) interviews every household member aged 14 and over, about 87,000 people a year, and records the main-job wage of about 25,000 employees. It asks for both the gross and the take-home wage; I use the gross wage, as in EPEN.

Gross pay. The payroll records gross wages, so the survey wage must be gross as well. Figure A1 compares EPEN with ENAHO, which asks both for gross and for take-home pay. ENAHO’s take-home wage has a mass at S/870–915: workers at the minimum wage reporting their pay after the pension deduction. EPEN has none, and its distribution lines up with ENAHO’s gross wage.

Figure A1: EPEN reports gross pay



Notes: Monthly main-job wage of formal (top) and informal (bottom) private employees around the minimum wage, 2022 (May–December, when the minimum wage was S/1,025) and 2023. ENAHO gross, ENAHO take-home and EPEN. Informal spikes at S/780, S/866, S/1,083 and S/1,300 are weekly pay converted to months.

Who pays the health insurance. Table A1 shows, for employees of private employers with any health insurance, who pays for it. A tenth are insured through a family member or pay themselves, and among workers over 60 a further sixth are insured as pensioners in 2022, and a fifth in 2023. Their current jobs need not be on any payroll. I keep only employees whose insurance is paid by their employer.

Table A1: Who pays the health insurance of private employees (%)

	2022			2023		
	Employer	Pension	Self or family	Employer	Pension	Self or family
Under 30	88.3	0.0	11.7	90.6	0.0	9.4
30–60	88.7	0.4	11.0	90.7	0.5	8.8
Over 60	63.8	17.1	19.1	60.8	21.3	17.9
All	87.2	1.2	11.6	89.1	1.5	9.5

Notes: EPEN, employees of private employers with a wage and affiliated to EsSalud, a private insurer, an EPS or the armed forces' and police scheme; question 362, who pays the contributions. Weighted.

Cells. Table A2 shows how the number of survey respondents per cell falls as variables are added to the cell definition. Every payroll cell has thousands of workers, so the survey is the binding constraint. With firm size and sector, every cell has at least 31 respondents in EPEN. Adding three age groups leaves a quarter of the cells below 30; adding region and education as well leaves half of the cells with fewer than 10. I therefore keep age, sex and region out of the cell definition and balance them by reweighting within cells. Table A3 reports the balance before and after reweighting.

Table A2: Survey respondents per cell as covariates are added to the cell definition

Cells defined by	Cells	Survey respondents per cell			% of cells with	
		Min.	10th pct.	Median	<10	<30
<i>EPEN 2022</i>						
Firm size	4	3,564	3,641	5,495	0	0
× sector	24	31	222	554	0	0
× age group	72	3	9	143	11	25
× Lima	144	0	2	49	26	43
× education	432	0	0	10	49	68
<i>EPEN 2023</i>						
Firm size	4	3,484	3,699	6,164	0	0
× sector	24	34	217	634	0	0
× age group	72	0	6	147	15	25
× Lima	144	0	1	52	24	44
× education	432	0	0	10	49	66
<i>ENAH0 2022</i>						
Firm size	4	775	866	1,404	0	0
× sector	24	12	55	162	0	4
× age group	72	0	3	38	28	46
× Lima	144	0	1	14	44	65
× education	432	0	0	3	68	87
<i>ENAH0 2023</i>						
Firm size	4	869	930	1,430	0	0
× sector	24	11	61	176	0	4
× age group	72	1	5	34	25	49
× Lima	144	0	1	14	40	64
× education	432	0	0	3	69	87

Notes: Firm size: 1–10, 11–100, 101–500, more than 500 workers. The binding constraint is the survey: every cell has thousands of payroll workers. Cells with at least one payroll worker; respondents counted with zeros. Each step adds one covariate to the previous one: age under 30, 30–60, over 60; Lima Metropolitana and Callao against the rest; education less than complete secondary, complete secondary, complete tertiary (including postgraduate). Payroll workers with the added covariate missing are left out of that step. Private formal employees in the estimation window; EPEN with employer-paid health insurance. The headline uses firm size × sector, with the survey reweighted within cells to the payroll’s age, sex and Lima shares.

7.2. The top of the estimation window

Household surveys under-represent high earners, so above some wage the survey stops describing the same workers as the payroll. I end the estimation window at the 96th percentile of the self-reported wages of formal employees above the minimum wage. No test locates this point: studies that combine surveys with tax records choose the percentile at which the two sources start to diverge (Blanchet et al., 2022). I measure the divergence

Table A3: Balance before and after reweighting within cells (total variation distance, percentage points)

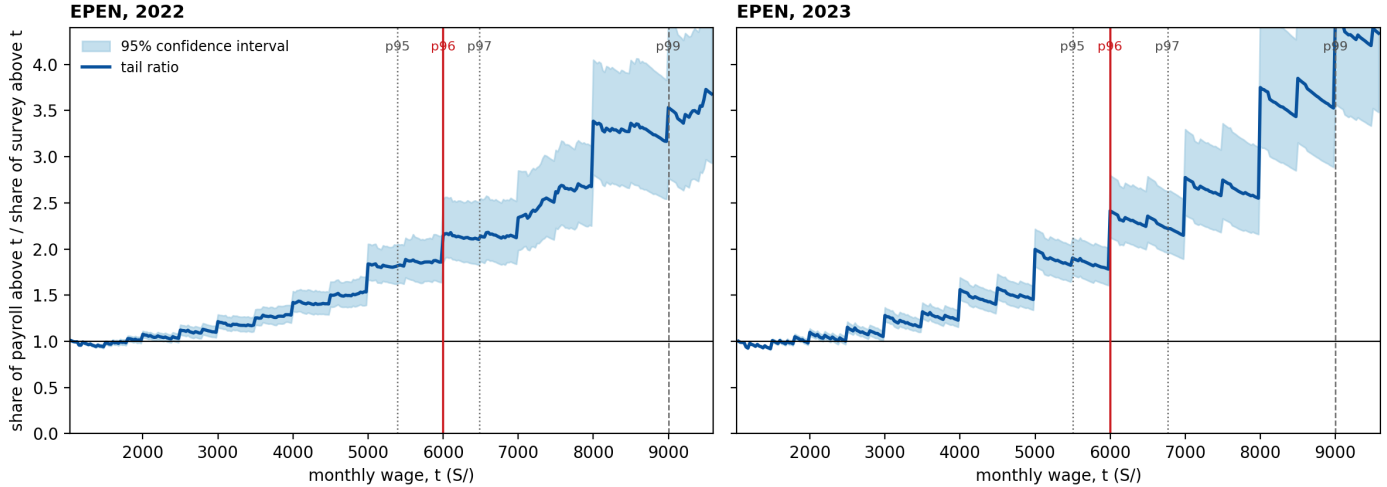
	Age group		Sex		Lima	
	Before	After	Before	After	Before	After
2022	11.6	6.8	8.1	6.8	7.7	0.0
2023	10.1	6.5	8.0	6.5	6.6	0.0

Notes: Average over cells, weighted by payroll workers, of the total variation distance between the payroll's and the survey's composition. The distance left on age and sex after reweighting is the share of payroll records with no age or sex recorded, which reweighting cannot match. EPEN, employer-paid health insurance.

with the tail ratio, the share of payroll workers above a wage divided by the share of survey respondents above it, both among workers above the minimum wage.

Figure A2 plots the tail ratio for EPEN, and Table A4 reports it at candidate cuts for both surveys. Up to about $S/2,000$ the ratio is close to one: the two sources place the same share of workers above each wage. It then rises steadily. At the 96th percentile ($S/6,000$ in EPEN), the payroll has about twice the survey's share of workers above the cut. Beyond it, the ratio climbs to between 3 and 4.5 at the 99th percentile, the number of respondents above the cut falls to about 150 in EPEN and about 50 in ENAHO, and the confidence intervals widen. The ratio rises faster beyond the 97th percentile. The 96th and 97th percentiles give similar ratios; I use the 96th, and the 97th would be an equally reasonable choice.

Figure A2: Payroll relative to survey above each wage



Notes: EPEN, private formal employees above the minimum wage. Tail ratio: share of payroll workers above t divided by the share of survey respondents above t (survey weighted). Shaded: 95% confidence interval from a bootstrap that resamples primary sampling units within strata. Vertical lines: percentiles of the self-reported wages of formal employees above the minimum wage; the estimation window ends at the 96th (solid). The steps come from survey respondents' heaping at round numbers.

Table A4: The top of the estimation window: candidate cuts and tail ratios

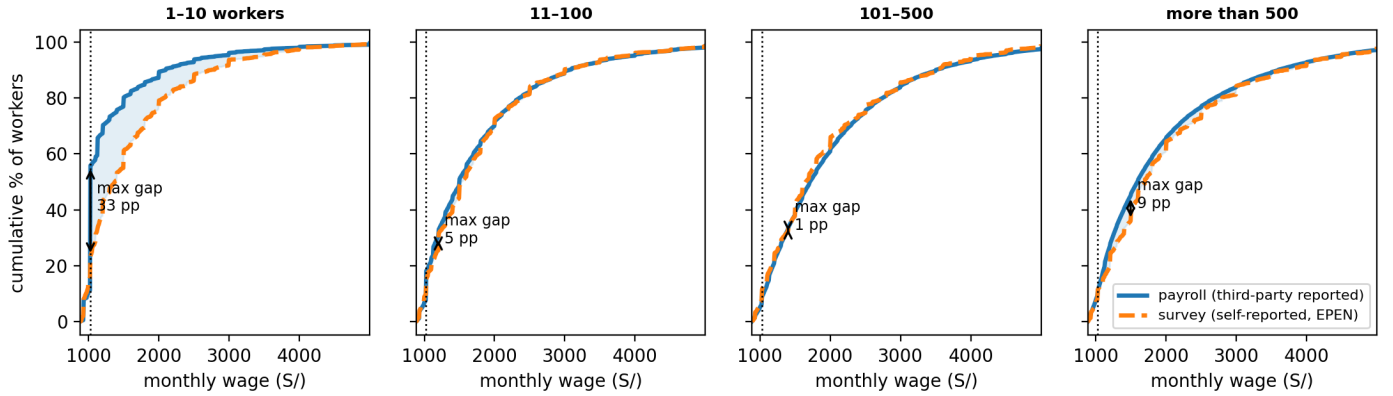
	EPEN 2022		EPEN 2023		ENAO 2020		ENAO 2021		ENAO 2022		ENAO 2023	
	Cut (S/)	Ratio	Cut (S/)	Ratio	Cut (S/)	Ratio	Cut (S/)	Ratio	Cut (S/)	Ratio	Cut (S/)	Ratio
p90	4,158 [1825]	1.41 (1.30, 1.55)	4,500 [1603]	1.58 (1.46, 1.73)	3,849 [395]	1.55 (1.35, 1.85)	3,971 [416]	1.61 (1.36, 1.93)	4,096 [432]	1.58 (1.34, 1.90)	4,086 [480]	1.83 (1.60, 2.10)
p93	4,900 [1376]	1.53 (1.40, 1.71)	5,000 [1071]	2.00 (1.81, 2.22)	4,324 [306]	1.79 (1.52, 2.12)	4,489 [285]	1.97 (1.66, 2.50)	4,748 [320]	1.72 (1.41, 2.17)	4,770 [348]	2.00 (1.72, 2.38)
p95	5,390 [957]	1.81 (1.62, 2.04)	5,500 [924]	1.90 (1.72, 2.12)	4,990 [230]	2.01 (1.65, 2.51)	5,027 [226]	2.17 (1.81, 2.87)	5,245 [236]	1.90 (1.53, 2.45)	5,119 [265]	2.37 (1.95, 2.84)
p96 (headline)	6,000 [614]	2.14 (1.85, 2.54)	6,000 [655]	2.41 (2.13, 2.80)	5,079 [188]	2.27 (1.83, 2.83)	5,239 [192]	2.46 (1.96, 3.46)	5,895 [182]	1.97 (1.50, 2.55)	5,825 [215]	2.34 (1.86, 2.87)
p97	6,483 [561]	2.10 (1.83, 2.50)	6,763 [567]	2.22 (1.96, 2.63)	5,983 [138]	2.17 (1.72, 2.82)	6,097 [146]	2.26 (1.77, 3.28)	6,436 [136]	2.32 (1.77, 3.11)	6,484 [159]	2.51 (1.97, 3.13)
p98	7,315 [360]	2.52 (2.10, 2.97)	7,500 [362]	2.75 (2.33, 3.36)	6,981 [88]	2.51 (1.95, 3.38)	7,132 [106]	2.32 (1.69, 3.49)	7,290 [89]	2.78 (2.06, 4.03)	7,198 [122]	2.86 (2.23, 3.66)
p99	9,000 [154]	3.53 (2.77, 4.47)	9,000 [144]	4.50 (3.57, 5.60)	8,089 [49]	3.35 (2.41, 5.00)	8,410 [56]	3.05 (2.19, 4.89)	8,363 [44]	4.15 (2.78, 6.91)	8,257 [66]	3.98 (2.90, 5.33)

Notes: Workers above the minimum wage. Cut: percentile of the self-reported wages of formal employees above the minimum wage; the estimation window ends at the 96th. Ratio: share of payroll workers above the cut divided by the share of survey respondents above it (private formal employees; survey weighted); 95% confidence interval in parentheses, from a bootstrap that resamples primary sampling units within strata (200 replications). Survey respondents above the cut in brackets. Formal employees: health insurance paid by the employer.

7.3. Wage distributions: cumulative distributions and age

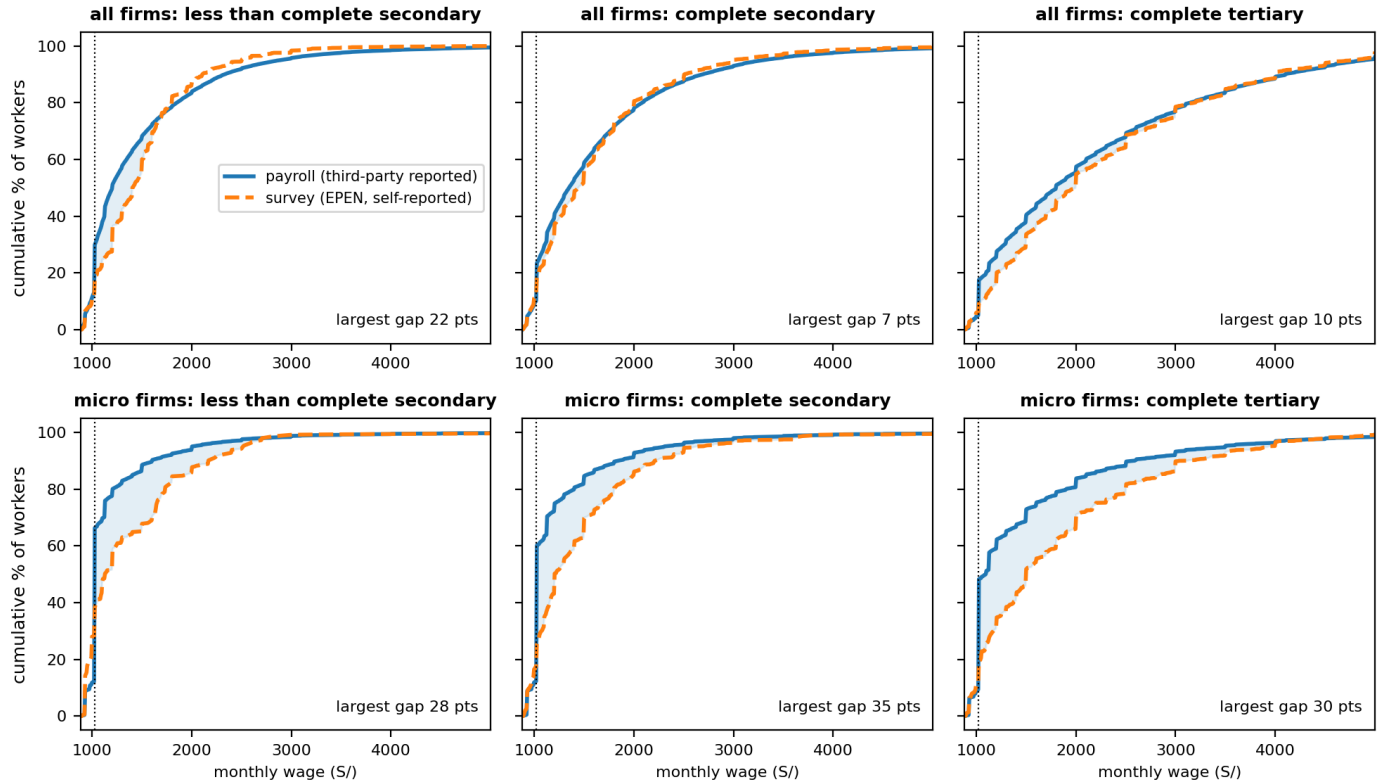
Figures A3 and A4 show the comparisons of Figures 1 and 2 as cumulative distributions, whose largest vertical gap is the lower bound on the extensive margin of Proposition 1(i) when the group is treated as a single cell. Figures A5 and A6 show the two distributions by age (Section 3.1).

Figure A3: Third-party reported and self-reported wage distributions, by firm size: cumulative distributions



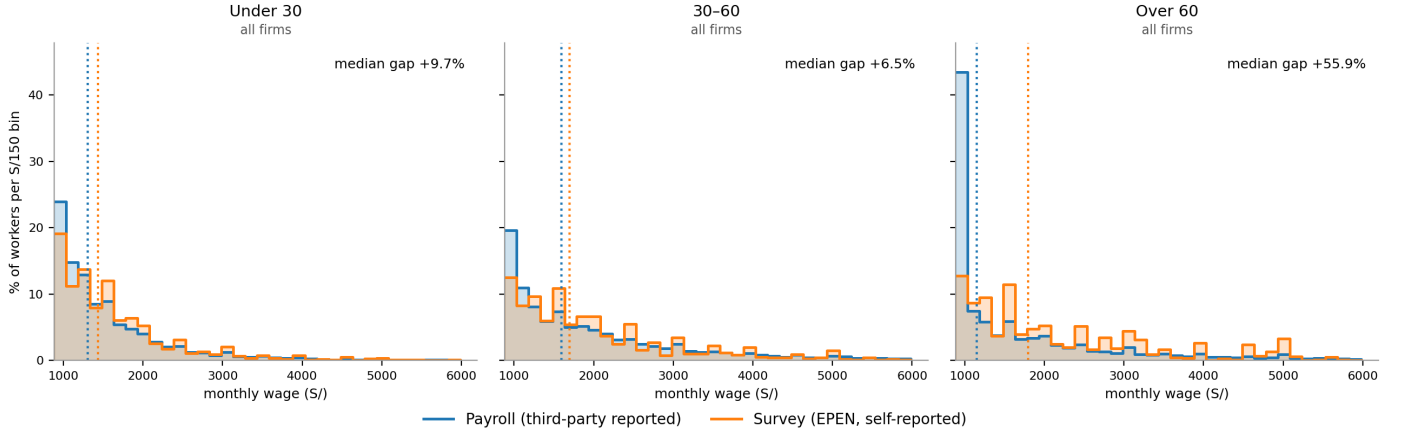
Notes: Cumulative distribution of monthly gross wages, private formal employees, 2022. Solid: payroll (third-party reported). Dashed: EPEN (self-reported). No cells and no reweighting. The dotted vertical line is the minimum wage.

Figure A4: Third-party reported and self-reported wage distributions, by education: cumulative distributions



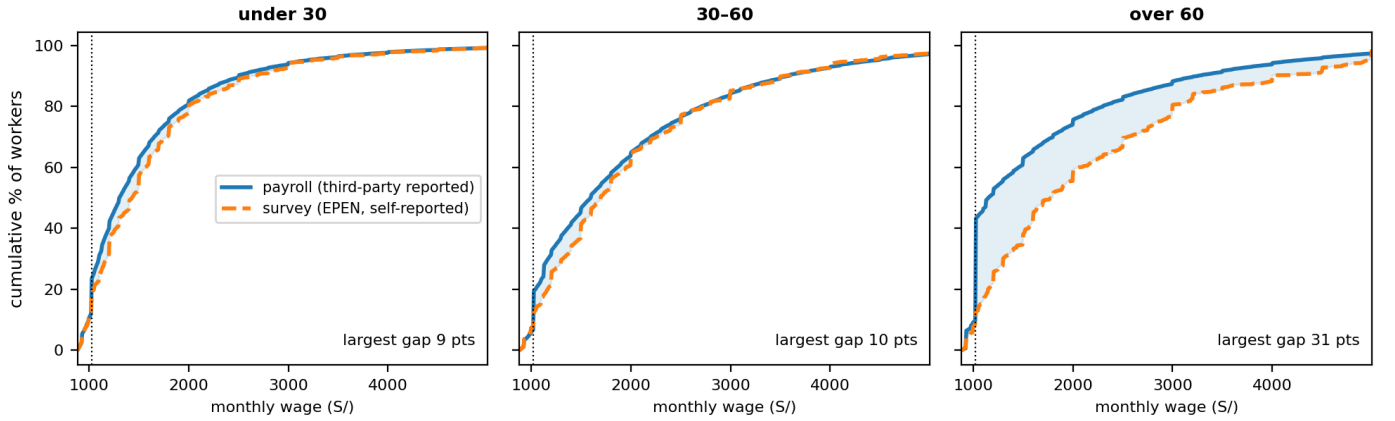
Notes: As Figure A3. Top row: all firms. Bottom row: micro firms (1–10 workers).

Figure A5: Third-party reported and self-reported wage distributions, by age



Notes: As Figure 1, by age group, all firms.

Figure A6: Third-party reported and self-reported wage distributions, by age: cumulative distributions



Notes: As Figure A3, by age group.

7.4. Cell-by-cell comparison: additional results

Table A5 reports the excess payroll mass at the 15th to 40th percentiles of the self-reported distribution. At the 15th percentile, the survey's own mass at the minimum wage falls on the percentile in some cells and years, and the measure becomes unstable; from the 25th percentile on, the pattern is the one of Table 5.

7.5. Proof of Proposition 1

Fix a cell and drop the subscript c . A pairing π is a joint distribution of $(\hat{w}, w)$ with marginals $F_{\hat{w}}$ and F_w , and Π is the set of all pairings. Quantile functions are $F^{-1}(u) = \inf\{x : F(x) \geq u\}$. With finitely supported distributions, such as the empirical ones I use, Π is a polytope and every infimum below is a minimum.

Table A5: Excess payroll mass at percentiles of the self-reported distribution (percentage points)

	2022						2023					
	p15	p20	p25	p30	p35	p40	p15	p20	p25	p30	p35	p40
<i>Firm size</i>												
All	2.0	5.8	7.6	7.8	7.8	6.8	6.4	5.9	7.2	5.6	4.8	5.2
1–10	4.1	21.3	31.1	29.0	29.5	28.1	33.3	32.5	34.5	30.6	30.7	28.8
11–100	3.3	3.5	3.4	2.0	1.8	2.7	–1.2	–0.6	–1.6	–1.6	–0.5	0.2
101–500	–1.6	–1.4	–1.6	–0.6	–0.6	–1.6	–5.2	–6.2	–5.2	–5.1	–7.4	–8.6
More than 500	1.9	2.5	2.1	4.3	4.0	2.0	1.0	0.1	2.7	0.6	–1.2	1.1

Notes: Share of payroll workers reported at or below the given percentile of self-reported wages, minus the respondents' own share at or below it. Private formal employees in the estimation window. Cells: firm size (1–10, 11–100, 101–500, more than 500 workers) by sector (agriculture, mining, manufacturing, construction, commerce, services); within cells, survey weights are reweighted to the payroll's shares by age group, sex and Lima. Group statistics average cells weighted by payroll workers.

(i) **Extensive margin.** For any pairing π and any wage x ,

$$F_{\hat{w}}(x) - F_w(x) = \Pr_{\pi}(\hat{w} \leq x < w) - \Pr_{\pi}(w \leq x < \hat{w}) \leq \Pr_{\pi}(\hat{w} \leq x < w) \leq \Pr_{\pi}(w > \hat{w}).$$

Taking the supremum over x , every pairing has an extensive margin of at least $\underline{e}$. A shifted-rank pairing attains it. Let U be uniform on $(0, 1]$, and set $\hat{w} = F_w^{-1}(U)$ and $w = F_{\hat{w}}^{-1}(V)$, with $V = U - \underline{e}$ if $U > \underline{e}$ and $V = U + 1 - \underline{e}$ otherwise. V is uniform, so this is a pairing. For $u \in (\underline{e}, 1]$, let $x = F_{\hat{w}}^{-1}(u)$. Then $F_{\hat{w}}(x) \geq u$, so $F_w(x) \geq F_{\hat{w}}(x) - \underline{e} \geq u - \underline{e}$, and $F_w^{-1}(u - \underline{e}) \leq x$. Hence $w \leq \hat{w}$ whenever $U > \underline{e}$, and $\Pr(w > \hat{w}) \leq \underline{e}$. The construction needs no continuity, so atoms and ties are covered. The formula is the upper bound of Fan and Park (2010) on $\Pr(w - \hat{w} \leq 0)$, from their Lemma 2.1; bounds of this kind go back to Makarov (1981), who states them for sums. In the data, the transport program that minimizes $\Pr_{\pi}(w > \hat{w})$ returns $\underline{e}$ in every cell (Appendix 7.6).

(ii) **Intensive margin.** Under π , let $N(\pi) = E_{\pi}[(\text{PUT}/\hat{w})^+]$ and $D(\pi) = \Pr_{\pi}(\text{PUT} > 0)$. Since $\hat{w} > 0$, $(\text{PUT}/\hat{w})^+ > 0$ exactly when $\text{PUT} > 0$, so the intensive margin is $N(\pi)/D(\pi)$. By (i), $D(\pi) \geq \underline{e} > 0$ for every π . Let

$$G(\xi) = \inf_{\pi \in \Pi} [N(\pi) - \xi D(\pi)].$$

G is the infimum of affine functions of ξ with slopes $-D(\pi) \leq -\underline{e} < 0$. It is therefore concave, hence continuous, and $G(\xi') \leq G(\xi) - (\xi' - \xi)\underline{e}$ for $\xi' > \xi$, so it is strictly decreasing. $G(0) = \underline{\rho} > 0$: by (iii), if $\underline{\rho}$ were zero, rank invariance would have $w \leq \hat{w}$ almost surely, and $\underline{e}$ would be zero. For any pairing π_0 , $G(\xi) < 0$ once $\xi > N(\pi_0)/\underline{e}$. So G has a unique root $\xi^* > 0$. At ξ^* , every pairing has $N(\pi) \geq \xi^* D(\pi)$, that is, $N(\pi)/D(\pi) \geq \xi^*$; and for every $\varepsilon > 0$ some pairing has $N(\pi) - \xi^* D(\pi) < \varepsilon$, so $N(\pi)/D(\pi) < \xi^* + \varepsilon/\underline{e}$. Hence $\underline{\rho} = \xi^*$. With finite support, the infimum is attained, and the minimizing pairing has $N(\pi)/D(\pi) = \xi^*$. Because N and D are both linear in π , each $G(\xi)$ is an optimal transport problem with cost $(w/\hat{w} - 1)^+ - \xi \mathbf{1}\{w > \hat{w}\}$. The algorithm of Dinkelbach (1967) starts from a trial value ξ_0 , solves this problem, and updates ξ to $N(\pi)/D(\pi)$ at the solution. The first update is the ratio of a feasible pairing, so $\xi_1 \geq \xi^*$, and each later update lowers ξ strictly until $G(\xi) = 0$. With each solution taken at one of the finitely many vertices of Π , the algorithm stops at ξ^* after finitely many steps. In every cell and group, it stops within six iterations.

(iii) **Average PUT rate.** Under π , the average PUT rate is $E_\pi[h(\hat{w}, w)]$, with $h(\hat{w}, w) = (w/\hat{w} - 1)^+$. The function h is submodular: for $\hat{w} \leq \hat{w}'$ and $w \leq w'$,

$$h(\hat{w}, w) + h(\hat{w}', w') \leq h(\hat{w}, w') + h(\hat{w}', w).$$

To see this, write $h = \chi(\log w - \log \hat{w})$, with $\chi(t) = (e^t - 1)^+$, which is convex. Of the four differences, $a = \log w - \log \hat{w}'$ is the smallest and $d = \log w' - \log \hat{w}$ the largest; the other two, $b = \log w - \log \hat{w}$ and $b' = \log w' - \log \hat{w}'$, lie between them, and $b + b' = a + d$. By convexity of χ , $\chi(b) + \chi(b') \leq \chi(a) + \chi(d)$, which is the inequality above; with a tie, both sides are equal. For a right-continuous submodular function k with $E[k(\hat{w}, w_0)]$ and $E[k(\hat{w}_0, w)]$ finite for some $\hat{w}_0$ and w_0 , the expectation over all pairings is smallest under the comonotone pairing and largest under the antitone pairing (Cambanis et al., 1976). Here h is continuous and $0 \leq h \leq w/\underline{w}$, so $E[w] < \infty$ is enough. The comonotone pairing is rank invariance, $(\hat{w}, w) = (F_{\hat{w}}^{-1}(U), F_w^{-1}(U))$ with U uniform on $[0, 1]$. With heaping, it pairs a mass point of reported wages with a range of true-wage percentiles, so it is a pairing but not a function of $\hat{w}$. Substituting it gives $\underline{\rho}$. The same argument with $(w - \hat{w})^+$, a convex function of $w - \hat{w}$, gives the second form of γ^+ in Section 4.3.

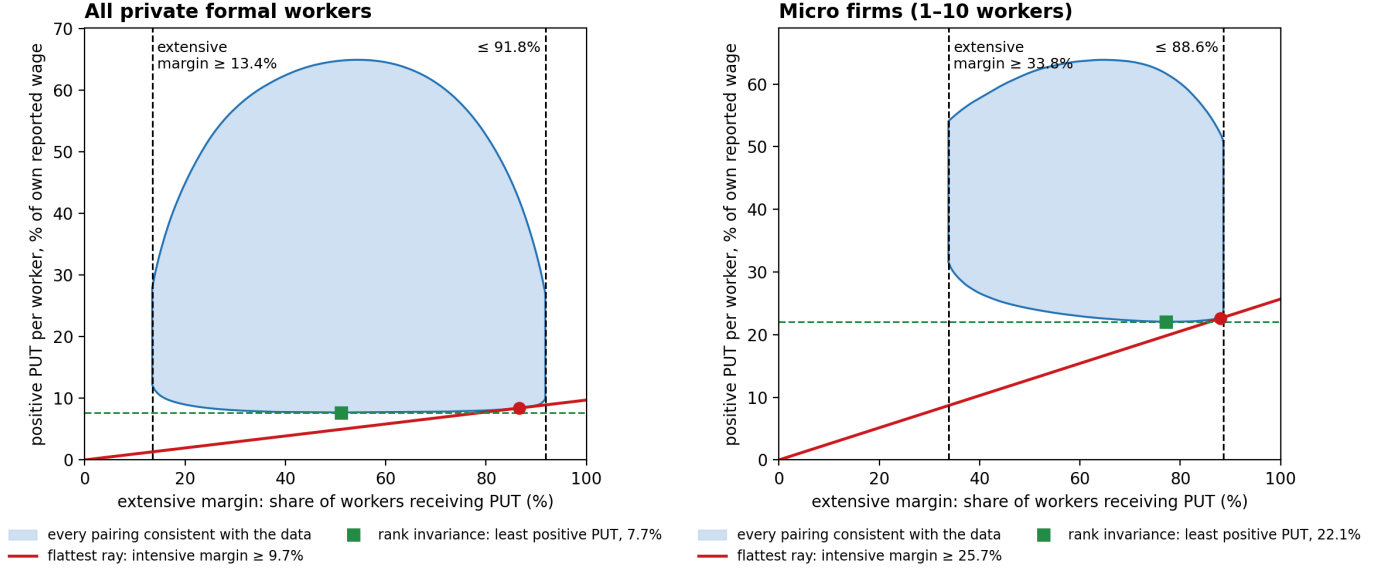
Groups of cells. For a group of cells with payroll weights n_c , the extensive margin and the average PUT rate are averages of the cells' values weighted by n_c , and the pairing in one cell does not affect another, so each lower bound is the weighted average of the cell lower bounds. The intensive margin of the group is $\sum_c n_c N_c(\pi_c) / \sum_c n_c D_c(\pi_c)$, a ratio of sums, so its lower bound is not the weighted average of the cell lower bounds and can lie above or below it. The argument of (ii) applies with $G_g(\xi) = \sum_c n_c \inf_{\pi_c} [N_c(\pi_c) - \xi D_c(\pi_c)]$, which separates by cell for each ξ but has a single root for the group. It requires only that $\sum_c n_c \underline{e}_c > 0$; cells with $\underline{e}_c = 0$ enter G_g like any other.

7.6. Bounds on the margins: additional results

An example with two workers. Suppose two workers are reported at S/1,000 and S/1,100, and two comparable respondents report S/1,050 and S/1,150. Under Assumption 1, these are the workers' true wages, in some order. Matching by rank, both workers receive PUT, 5% and 4.5% of their reported wages: the extensive margin is 100%, and the intensive margin and the average PUT rate are both 4.8%. Matching the other way, the first worker receives 15% and the second has a true wage 4.5% below the reported one: the extensive margin is 50%, the intensive margin 15%, and the average PUT rate 7.5%. The lower bounds are therefore 50% on the extensive margin, from the second pairing, and 4.8% on the other two, from the first. A pairing that concentrates PUT on few workers minimizes the extensive margin, and one that spreads it over many minimizes the intensive margin. For the same reason, the lower bounds do not multiply: 50% times 4.8% is 2.4%, half the lower bound on the average PUT rate.

Every pairing at once. Figure A7 shows all the pairings consistent with the data, for the economy and for micro firms in 2022. The three lower bounds sit on three different edges of the set: the left edge for the extensive margin, the lowest point for the average PUT rate, and the flattest line from the origin for the intensive margin. No single pairing attains all three, which is why the lower bounds do not multiply.

Figure A7: Every pairing consistent with the data



Notes: EPEN, 2022. Each pairing of reported and true wages within cells is one point: its horizontal position is the extensive margin, the share of workers who receive PUT, and its height is the average PUT rate, the average PUT across all workers as a share of the reported wage. The intensive margin is height divided by width, the slope of the line from the origin to the point. The shaded area contains every pairing consistent with the data. Dashed vertical lines: the lower bound and the ceiling on the extensive margin. Square: rank invariance, the lowest point, which attains the lower bound on the average PUT rate. Solid line: the flattest line from the origin that touches the area; its slope is the lower bound on the intensive margin. Each cell's payroll is represented by 100 quantiles, so the values in the figure differ from Table 6 by a few tenths.

Ceiling and threshold. For any pairing and any wage x , $\{w \leq x\} \subseteq \{w \leq \hat{w}\} \cup \{\hat{w} < x\}$, so $\Pr(w \leq \hat{w}) \geq F_w(x) - F_{\hat{w}}(x^-)$, where $F_{\hat{w}}(x^-) = \Pr(\hat{w} < x)$. The extensive margin is therefore at most $\bar{e} = 1 - \sup_x [F_w(x) - F_{\hat{w}}(x^-)]$. With finitely supported distributions, this ceiling is attained by the pairing in the proof of (i) with $V = U + 1 - \bar{e}$ if $U \leq \bar{e}$ and $V = U - \bar{e}$ otherwise. The left limit matters: with $F_{\hat{w}}(x)$ in its place, the bound would count as PUT the workers whose two wages coincide at a mass point. Applying (i) to $(1 + \delta)\hat{w}$ gives, for $\delta > -1$, the lower bound on the share of workers whose PUT exceeds a fraction δ of the reported wage, $\sup_x [F_{\hat{w}}(x) - F_w((1 + \delta)x)]$, which is non-negative and attained. Table A6 reports the ceiling and this lower bound at $\delta = 15\%$. The lower bound at $\delta = 15\%$ guards against small overstatements in the survey. If the survey understates, it is still a lower bound on the share of workers whose PUT exceeds 15% of the reported wage; and if respondents may overstate their true wage by up to 15%, it is still a lower bound on the share who receive any PUT, because a self-reported wage more than 15% above the reported one then implies a true wage above the reported one. The ceiling is close to 90% and uninformative on its own. Since $(w/\hat{w} - 1)^+$ is submodular, the reverse-rank pairing $(F_{\hat{w}}^{-1}(U), F_w^{-1}(1 - U))$ maximizes the average PUT rate (Cambanis et al., 1976); this ceiling is several times the lower bound and equally uninformative.

Negative gaps and rank invariance. Table A7 reports the three quantities under three assumptions on negative gaps, a true wage below the reported wage. With no assumption, each column is the least value over all pairings. Under rank invariance, the values are those of one pairing, with the same pairing applied to the payroll against a subsample of itself, where no gap is real, in brackets. With negative gaps only where the

Table A6: Ceiling on the extensive margin and lower bound on the share with PUT above 15% of the reported wage (%)

	2022		2023	
	Ceiling	PUT > 15%	Ceiling	PUT > 15%
All	91.7	6.3	86.8	7.4
1–10	88.5	20.7	80.8	26.5
11–100	92.0	1.4	85.8	1.2
101–500	92.6	1.6	88.5	0.8
More than 500	92.9	4.1	90.4	3.1
Agriculture	97.0	20.8	94.7	20.1
Mining	88.5	12.8	91.3	12.4
Manufacturing	93.2	3.3	89.4	6.0
Construction	97.7	10.5	90.8	9.3
Commerce	85.4	6.0	80.1	9.1
Services	91.7	3.9	86.6	5.2

Notes: Least and largest values over all pairings, by cell, averaged over cells weighted by payroll workers. Private formal employees in the estimation window. Cells: firm size (1–10, 11–100, 101–500, more than 500 workers) by sector (agriculture, mining, manufacturing, construction, commerce, services); within cells, survey weights are reweighted to the payroll’s shares by age group, sex and Lima. Group statistics average cells weighted by payroll workers.

two distributions force them, the columns are lower bounds over the pairings that keep negative gaps at that minimum. A negative gap can reflect over-declaration by the employer or a self-report below the true wage, and the data cannot tell them apart. On the 100-point grid of Table A7, the extensive margin moves from 13.4% to 78.4% across these assumptions in 2022 (13.2% in Table 6, which uses the full distributions), the intensive margin from 9.7% to 10.7%, and the average PUT rate from 7.7% to 9.5%. For all workers, the negative gaps of rank invariance are of the size that sampling noise from finite survey cells alone produces (41.3% against 40.7% in 2022); at micro firms and in agriculture they are far below it. The extensive margin under rank invariance (51.2% in 2022) is not informative on its own: it counts every small positive gap as PUT, and the same pairing returns 37.8% when the payroll is set against a subsample of itself, where there is no PUT.

Sampling noise. This paragraph is about sampling noise, not measurement error: it would arise even if every respondent reported their wage exactly, because each survey cell has a finite number of respondents. Measurement error is in Appendix 7.7. Survey cells are finite, and sampling noise makes two distributions look more different than they are, which pushes every lower bound up. I report two gauges. The *placebo* draws a subsample of the payroll with each cell’s number of survey respondents and treats it as the survey: since the two distributions then coincide, any value the method returns is noise. For the extensive margin, I also report the precision-corrected estimate of Chernozhukov et al. (2013), which discounts each wage’s gap by its standard error before taking the largest. Confidence bounds are one-sided at 95%, from a bootstrap that resamples the survey’s primary sampling units within strata. Table A8 reports the gauges.

Program and closed form. The lower bound on the extensive margin, its ceiling and the lower bound on the average PUT rate have closed forms, and each is also the solution of an optimal transport problem over all

Table A7: The two margins under three assumptions on negative gaps (%)

	2022				2023			
	Ext.	Neg.	Int.	Avg.	Ext.	Neg.	Int.	Avg.
All								
No assumption (least values)	13.4	74.6	9.7	7.7	13.9	67.8	11.9	8.3
Rank invariance	51.2 [37.8]	41.3 [40.7]	15.1	7.7	46.2 [39.5]	40.6 [35.6]	17.9	8.3
Negative gaps only where forced	78.4	5.6	10.7	9.5	72.0	6.3	12.9	10.6
1–10								
No assumption (least values)	33.8	41.1	25.7	22.1	38.3	23.9	33.8	27.1
Rank invariance	77.2 [21.4]	10.5 [15.0]	28.6	22.1	79.1 [16.0]	1.9 [16.3]	34.3	27.1
Negative gaps only where forced	66.9	5.2	27.3	23.2	60.0	1.4	34.4	27.7
Agriculture								
No assumption (least values)	36.9	59.9	18.8	17.9	35.4	59.0	15.8	14.3
Rank invariance	88.7 [54.9]	10.7 [41.3]	20.1	17.9	79.7 [47.0]	17.9 [46.8]	17.9	14.3
Negative gaps only where forced	93.3	2.9	19.1	18.5	89.5	4.2	15.8	14.8

Notes: Ext.: extensive margin. Neg.: share of workers with a negative gap (true wage below the reported wage). Int.: intensive margin. Avg.: average PUT rate. No assumption: each column is the least value over all pairings; Neg. is the share in the pairing that attains the least extensive margin. Rank invariance: one pairing; in brackets, the same pairing applied to the payroll against a subsample of itself with each cell's number of survey respondents, where no gap is real (average of 20 draws). Negative gaps only where forced: Neg. is the least share any pairing allows, and the other columns are least values over the pairings that keep it there. Payroll on a 100-point grid per cell, so the least extensive margin differs from Table 6 by a few tenths. Private formal employees in the estimation window. Cells: firm size (1–10, 11–100, 101–500, more than 500 workers) by sector (agriculture, mining, manufacturing, construction, commerce, services); within cells, survey weights are reweighted to the payroll's shares by age group, sex and Lima. Group statistics average cells weighted by payroll workers.

Table A8: Sampling noise from finite survey cells: placebo and precision correction, 2022 (%)

	Extensive margin			Intensive margin		Average PUT rate	
	Lower bound	Corrected	Placebo	Lower bound	Placebo	Lower bound	Placebo
All	13.2	11.6	1.6	9.7	1.3	7.7	0.6
1–10	33.5	31.7	1.9	25.7	3.2	22.0	0.5
11–100	6.3	4.9	1.3	5.2	1.3	3.7	0.5
101–500	4.7	3.2	2.0	4.1	1.4	2.4	0.8
More than 500	10.8	9.2	1.5	6.4	1.1	5.1	0.6
Agriculture	36.8	35.1	2.0	18.8	1.1	17.8	0.8
Construction	18.0	14.1	3.2	16.6	2.0	15.4	0.9

Notes: Lower bound: least value over all pairings. Corrected: precision-corrected estimate of Chernozhukov et al. (2013). Placebo: the same statistic when the survey is replaced by a subsample of the payroll with each cell's number of survey respondents, averaged over 20 draws; any value it returns is noise. EPEN, employer-paid health insurance. Private formal employees in the estimation window. Cells: firm size (1–10, 11–100, 101–500, more than 500 workers) by sector (agriculture, mining, manufacturing, construction, commerce, services); within cells, survey weights are reweighted to the payroll's shares by age group, sex and Lima. Group statistics average cells weighted by payroll workers.

pairings in a cell. Solving the transport problems directly returns the closed forms in every cell, year and survey, up to 3×10^{-13} percentage points. The lower bound on the intensive margin is computed only as a transport program; it coincides with the slope of the flattest line from the origin in Figure A7.

7.7. Reporting error

This section is about measurement error: the difference between each respondent’s report and their true wage. Unlike the sampling noise of Appendix 7.6, it does not shrink as the survey grows.

Measuring the reporting noise. Write the survey’s log wage as $\log \tilde{w} = \log w + m + s z$, where m is a constant, z is standard normal and independent of the true wage w , and s is the size of the noise. Assumption 1 sets $m = s = 0$; a survey that understates without noise has $m < 0$ and $s = 0$, which only lowers the estimates (Section 3.2). Because the two sources cannot be linked, m and s cannot be estimated among private employees, where PUT and noise both separate the two distributions. I estimate them where there is no PUT, following Paulus (2015): public employees with a permanent appointment in education and health, whom ENAHO identifies and whose gross pay, including the allowances that carry no contributions, the government payroll (AIRHSP) records. For each year, I choose m and s so that the distribution of $w \exp(m + s z)$, with w drawn from the payroll, is closest to the survey’s in Cramér–von Mises distance, both inside the estimation window. Panel A of Table A10 reports the estimates. Respondents understate their pay by about 13%, and the noise has a standard deviation between 0.08 and 0.15 log points (at most 0.19 in 2022, with 95% confidence).²⁴ Allowing the error to depend on the true wage gives a positive slope in every year: low earners understate more. With linked Estonian data, Paulus (2015) finds the opposite pattern, low earners overstating, as do validation studies in the United States (Bound and Krueger, 1991; Bollinger, 1998).

Reporting noise alone. Table A9 replaces the survey with payroll wages times $\exp(e)$, $e \sim N(-s^2/2, s^2)$, so that reports are right on average and there is no PUT, and applies the method. Each cell draws its number of respondents from all its payroll records, including those outside the window, and then cuts the reports to the window, as the survey is cut. At the noise measured among public employees, the lower bounds on PUT above 15% of the reported wage, on the intensive margin and on the average PUT rate stay well above what noise produces at micro firms, in agriculture and in construction; to produce them, the noise would have to be at least twice as large. The lower bound on the extensive margin, which counts any positive gap, is the most exposed: noise spreads the payroll’s spike at the minimum wage to both sides of it, and the half pushed above the minimum looks like PUT. When workers paid a statutory minimum report it exactly, noise produces at most 5.7% on any lower bound in the table.

Tests at the minimum wage. Panels B and C of Table A10 check the two ways in which reporting error could produce the lower bounds near the minimum wage. If workers paid the minimum misreported it in both directions, the survey would have 3.3% of respondents just below the minimum (6.3% at micro firms); it has 1.3% (1.7%, with a standard error of 0.4). If low earners overstated their wage, as in Paulus (2015), the survey

²⁴The fit attributes to noise any part of the gap that is not a constant share, such as a larger understatement at the bottom, so it overstates s .

Table A9: Reporting error: what reporting noise alone produces, 2022 (%)

		Noise alone, no PUT			
	Estimate	0.15	0.19	0.19, exact at minimum	Noise needed
<i>Extensive margin</i>					
All	13.2	9.2	10.1	2.8	0.36
1–10	33.5	28.9	31.1	2.4	0.25
Agriculture	36.8	7.1	8.4	5.7	>0.50
Construction	18.0	8.6	9.1	3.2	>0.50
<i>Extensive margin, PUT above 15% of the reported wage</i>					
All	6.3	0.6	1.5	0.1	>0.50
1–10	20.7	3.0	7.4	0.2	0.40
Agriculture	20.8	0.3	0.4	0.2	>0.50
Construction	10.5	0.8	1.5	0.1	>0.50
<i>Intensive margin</i>					
All	9.7	3.5	4.3	2.0	>0.30
1–10	25.7	8.6	10.8	3.4	>0.30
Agriculture	18.8	3.4	4.4	3.1	>0.30
Construction	16.6	2.9	4.0	2.3	>0.30
<i>Average PUT rate</i>					
All	7.7	2.9	3.8	1.3	0.34
1–10	22.0	6.6	8.7	0.9	0.43
Agriculture	17.8	3.0	3.9	3.0	>0.50
Construction	15.4	2.8	3.5	1.1	>0.50

Notes: Estimate: the lower bound in Table 6. Noise alone: the same lower bound when the survey is replaced by payroll wages times $\exp(e)$, $e \sim N(-s^2/2, s^2)$, drawn for each cell's number of respondents from all the cell's payroll records and then cut to the estimation window, averaged over 20 draws (5 for the intensive margin); $s = 0.15$ is the noise measured among public employees in 2022 and 0.19 its upper 95% bound (Table A10). Exact at minimum: workers paid a statutory minimum (the minimum wage, or the minimum plus the family allowance) report it without error. Noise needed: the value of s at which noise alone reaches the estimate, by linear interpolation on a grid up to 0.50 (0.30 for the intensive margin). EPEN, employer-paid health insurance. Private formal employees in the estimation window. Cells: firm size (1–10, 11–100, 101–500, more than 500 workers) by sector (agriculture, mining, manufacturing, construction, commerce, services); within cells, survey weights are reweighted to the payroll's shares by age group, sex and Lima. For a group, the lower bounds on the extensive margin and on the average PUT rate average the cell lower bounds, weighted by payroll workers; the lower bound on the intensive margin chooses the pairings of all the group's cells jointly.

would have fewer low-paid workers than the payroll at every firm size. Outside agriculture, in firms with more than 100 workers, it has slightly more: 17.9% of respondents are paid at most 1.1 times the minimum, against 16.0% of payroll workers (standard error 0.7). At micro firms it has half as many (33.2% against 65.5%). In agriculture, large firms show a gap of the same kind.

Table A10: Reporting error: size, and tests at the minimum wage (%)

<i>A. Public employees in education and health: survey against the government payroll</i>				
	Noise	Upper 95% bound	Understatement (%)	Slope on true wage
2020	0.10	0.15	15.0	+0.20
2021	0.08	0.11	12.0	+0.10
2022	0.15	0.19	13.0	+0.25
2023	0.15	0.19	15.0	+0.20
<i>B. Paid 0.95 to 0.99 times the minimum wage, 2022</i>				
	Payroll	Survey	(SE)	Noise alone, 0.15
All	1.3	1.3	(0.2)	3.3
1–10	0.4	1.7	(0.4)	6.3
<i>C. Paid at most 1.10 times the minimum wage, 2022</i>				
	Payroll	Survey	(SE)	
1–10, all sectors	65.5	33.2	(1.4)	
11–100, outside agriculture	26.2	21.8	(0.9)	
101–500, outside agriculture	15.0	18.7	(1.1)	
More than 500, outside agriculture	16.7	17.5	(0.8)	
101–500, agriculture	37.1	11.6	(2.4)	
More than 500, agriculture	42.9	12.1	(1.4)	

Notes: Panel A: ENAHO public employees with a permanent appointment in education and health against the government payroll (AIRHSP) in June, gross pay, inside the estimation window. The survey's log wage is modeled as the true log wage plus a constant (the understatement) plus normal noise; noise is its standard deviation, fitted by minimum Cramér–von Mises distance between the two distributions, with the upper bound from 50 bootstrap samples of respondents. Slope: the same fit with the error allowed to depend on the true wage; a positive slope means low earners understate more. Panel B: payroll, survey and the survey that noise alone would produce (Table A9), averaged over cells weighted by payroll workers. Panel C: the minimum plus the family allowance; survey weights. Standard errors from a bootstrap that resamples the survey's primary sampling units within strata. EPEN, employer-paid health insurance, private formal employees in the estimation window.

Correcting for reporting noise. Simulation–extrapolation (Cook and Stefanski, 1994) adds more noise of the same kind to the survey, recomputes each statistic, and extrapolates back to no noise. With noise of the measured size and exact reporting at the minimum, it moves the lower bounds on the intensive margin and on the average PUT rate by at most 2.5 percentage points, for the economy, micro firms, agriculture and construction: the average PUT rate becomes 7.0% for the economy and 19.7% at micro firms. If every respondent's report carries the noise, it becomes 5.4% and 15.4%. Removing as well the understatement measured among public employees raises every lower bound: the average PUT rate becomes 18.5% and 34.1%. I do not apply the correction to the extensive margin: its lower bound jumps as soon as any noise spreads a spike in the survey, a jump that no smooth extrapolation can undo.

7.8. ENAHO, 2020–2023

ENAHO covers 2020–2023 with a sample about a quarter of EPEN’s. Tables 4, 5 and 6 report it alongside EPEN, with the same cells, definition of formal employees and code; Table A11 adds the mean and median gaps by sector. ENAHO reproduces the pattern of the EPEN results in every year: micro firms show the largest gaps, and firms with more than 10 workers small ones. Its mean gaps at micro firms are smaller than EPEN’s, while its median gaps, excess mass and lower bounds on the extensive margin are similar or larger. The cells, the definition of formal employees and the code are the same, so the difference comes from the surveys themselves, which differ in sample, questionnaire and fieldwork. In agriculture, the mean gap turns positive in 2021 (the median gap was already positive in 2020), the year a reform raised the sector’s payroll taxes and introduced a bonus for agricultural workers that survey respondents may report as income.

Table A11: ENAHO, 2020–2023: mean and median gaps within cells (%)

	2020		2021		2022		2023	
	Mean	Median	Mean	Median	Mean	Median	Mean	Median
All	4.2	7.6	1.7	5.9	2.8	8.7	1.8	9.3
1–10	19.7	27.8	19.2	35.1	18.5	33.5	17.7	39.3
11–100	1.3	4.4	–1.4	–2.4	0.1	2.8	–3.5	–1.3
101–500	–0.7	–0.1	–8.5	–7.3	–4.9	–4.2	–5.0	–2.1
More than 500	–0.4	1.7	–1.1	1.0	–0.2	5.7	–0.9	3.7
Agriculture	–2.4	5.7	7.5	19.5	10.4	25.6	10.8	26.1
Mining	8.2	19.5	9.7	12.4	2.6	7.9	4.9	6.4
Manufacturing	2.4	6.3	1.2	5.4	–0.0	0.7	–1.5	1.3
Construction	18.3	21.1	7.2	8.3	22.8	33.7	10.0	17.8
Commerce	1.2	2.0	–0.7	2.5	–0.1	4.6	1.0	6.2
Services	4.4	7.4	0.3	4.0	–0.1	5.3	0.7	9.3

Notes: As Table 4, with ENAHO as the survey. Private formal employees in the estimation window. Cells: firm size (1–10, 11–100, 101–500, more than 500 workers) by sector (agriculture, mining, manufacturing, construction, commerce, services); within cells, survey weights are reweighted to the payroll’s shares by age group, sex and Lima. Group statistics average cells weighted by payroll workers.

8. Appendix: Methodological

8.1. Optimal Income Tax: Perturbation Method

An alternative derivation of equation (22) in aggregate terms is to consider a marginal increase in the income tax rate ($d\tau > 0$) and analyze its effects on welfare. At the optimum, the total effect must be zero. First, there is a mechanical effect (ME): the government collects more revenue from workers in proportion to their reported wages and redistributes it to all workers. This increases welfare when redistribution preferences are non-zero:

$$\text{ME} = (1 - \bar{g})\hat{Z}d\tau \quad (34)$$

where $\bar{g}$ is the average welfare weight on workers (across arrangements), 1 is the normalized welfare weight of all individuals (non-workers and workers). That is, the government values \$1 to an individual the same as $\bar{g}$ dollars to a worker. $\hat{Z}$ is total reported labor income.

Second, there is a fiscal externality (FE): the increase in the income tax rate generates behavioral responses that affect government revenue. First, it reduces reported labor income in two ways: workers reduce their labor supply (captured by the aggregate elasticity e_1), and they shift more of their earnings into PUT (captured by the aggregate elasticity e_2). Both channels reduce the income tax base, lowering revenue. At the same time, however, greater underreporting increases the firm's taxable profits. This is because PUT are not deductible from corporate taxes. So, when a worker receives more of their wage informally, the firm reports lower labor costs and thus higher profits, on which it must pay the corporate tax rate t . From the planner's perspective, only a fraction of this additional profit tax revenue counts toward welfare, depending on how much the planner values firm profits (through the welfare weight g_π).

The net effect on revenue is:

$$\text{FE} = -\tau \frac{d\hat{Z}}{d\tau} + t(1 - g_\pi) \frac{d\hat{\Pi}}{d\tau} = \left[-\tau \left(e_1 - \underbrace{\frac{\text{PUT}}{\hat{Z}}}_{\gamma} e_2 \right) + t(1 - g_\pi) \underbrace{\frac{\text{PUT}}{\hat{Z}}}_{\gamma} e_2 \right] \hat{Z} \quad (35)$$

where $\hat{Z}$ is total reported labor income and $\hat{\Pi} = F(L) - \hat{Z}$ are reported profits, and PUT is total underreported wage income. $\gamma = \frac{\text{PUT}}{\hat{Z}}$ is the wage-weighted average PUT rate, defined as before. $e_1 = \frac{\partial \log L}{\partial \log(1-\tau)} = e_1^P(\alpha^P - \gamma) + e_1^F \alpha^F > 0$ is the labor supply elasticity of all workers in both arrangements weighted by their reported income as share of total income in the economy. It aggregates intensive and extensive margin responses in labor supply. $e_2 = \frac{\partial \log \text{PUT}}{\partial \log(1-\tau)} < 0$ is the intensive margin PUT elasticity only for workers in the PUT arrangement. Note that $e_1 - \gamma e_2$ is the ETI defined as before.

At the optimum, the marginal welfare gain from redistribution equals the marginal revenue loss (or gain) from behavioral responses:

$$\text{ME} + \text{FE} = 0 \quad (36)$$

Solving this condition yields the optimal income tax rate:

$$\tau^* = \frac{1 - \bar{g} - t(1 - g_\pi)e_2\gamma}{1 - \bar{g} + e_1 - e_2\gamma} \quad (37)$$

This expression is exactly the same as derived before and shows the trade-off introduced by PUT: PUT reduces income tax revenue (denominator) but raises corporate tax revenue (numerator).

8.2. Optimal Income Tax: Comparative statics of ETI with respect to the corporate tax

The elasticity of taxable income is

$$\text{ETI} = (\alpha^P - \gamma)e_1^P + \alpha^F e_1^F - \gamma e_2 + \alpha^P \eta^P + \alpha^F \eta^F, \quad (38)$$

where $\alpha^i = Z^i/\hat{Z}$ are income shares, $\gamma = \text{PUT}/\hat{Z}$ is the wage-weighted average PUT rate, e_1^i are labor-supply elasticities, e_2 is the PUT (hiding) elasticity, and η^i are wage elasticities (all with respect to $\log(1 - \tau)$).

Differentiating with respect to the corporate tax t and writing $x' \equiv \partial x / \partial t$,

$$\begin{aligned} \frac{d\text{ETI}}{dt} = & \underbrace{\alpha^{P'}(e_1^P + \eta^P) + \alpha^{F'}(e_1^F + \eta^F) - \gamma'(e_1^P + e_2)}_{\text{Composition}} \\ & + \underbrace{\alpha^P(e_1^{P'} + \eta^{P'}) + \alpha^F(e_1^{F'} + \eta^{F'}) - \gamma(e_1^{P'} + e_2')}_{\text{Behavioral}} \end{aligned} \quad (39)$$

Recall the assumptions so far: (i) PUT is non-deductible; (ii) convex PUT costs; (iii) concave production, and (iv) small Frisch elasticities (hours response is locally small), so adjustments in aggregate labor supply come primarily from worker reallocation across arrangements.

There are two mechanisms through which t affects the ETI. First, there is a composition mechanism. A higher t raises the non-deductibility wedge, making PUT relatively more expensive. Firms substitute toward formal contracts, so the share of workers in the PUT arrangement decreases and the share in the formal arrangement increases. This also reduces aggregate PUT dollars in the economy (i.e., $\alpha^{P'} < 0$, $\alpha^{F'} > 0$, $\gamma' < 0$). Using $\alpha^{F'} = -\alpha^{P'} + \gamma'$ (since $\alpha^F + (\alpha^P - \gamma) = 1$), the composition term can be written as

$$\alpha^{P'}[(e_1^P + \eta^P) - (e_1^F + \eta^F)] + \gamma'[(e_1^F + \eta^F) - (e_1^P + e_2)]. \quad (40)$$

Under small Frisch elasticities and smooth wage pass-through (from concave production and the firm wedge), the first bracket is second-order. These effects are small in magnitude and are also proportional—one sector expands while the other contracts—so they partially offset, making the first bracket even smaller. The second bracket is positive because it contains the PUT elasticity $e_2 < 0$ and $\eta^F \leq 0$; with $\gamma' < 0$ this makes (i) negative. In short: the reallocation away from PUT reduces ETI. ²⁵

The second mechanism is the behavioral one. This is the more intuitive channel, as this captures how the elasticities themselves move with t :

$$\alpha^P(e_1^{P'} + \eta^{P'}) + \alpha^F(e_1^{F'} + \eta^{F'}) - \underbrace{\gamma(e_1^{P'} + e_2')}_{\text{PUT attenuation}}. \quad (41)$$

With convex PUT costs, a higher t strengthens the non-deductibility wedge and makes the PUT margin less responsive to $1 - \tau$: the PUT labor-supply elasticity moves toward zero ($e_1^{P'} > 0$) and the hiding elasticity moves

²⁵Formally, with $L^P = sL$, $L^F = (1 - s)L$ and $a \equiv 1 - \tau$, small intensive-hours responses imply $e_1^P \approx \frac{a}{s} \frac{ds}{da}$ and $e_1^F \approx -\frac{a}{1-s} \frac{ds}{da}$, so $e_1^P + e_1^F$ is modest. Smooth, wedge-linked pass-through keeps η^P and η^F of comparable order with opposite signs. Hence $(e_1^P + \eta^P) - (e_1^F + \eta^F) = a \frac{d}{da} \log\left(\frac{w^P s}{w^F (1-s)}\right) \approx 0$. In the second bracket, $(e_1^F + \eta^F) - (e_1^P + e_2) = (e_1^F - e_1^P) + (\eta^F - e_2)$ is typically > 0 because $e_1^F - e_1^P > 0$ (reallocation) and $-e_2 > 0$ dominates the smooth $\eta^F \leq 0$ under the baseline.

toward zero ($e'_2 > 0$). Hence the term $-\gamma(e_1^{P'} + e'_2)$ is strictly negative. This is the PUT attenuation term. The remaining pieces are second-order. Under concave production and the firm wedge $w^F = w^P + \frac{t}{1-t} \overline{\text{PUT}}$, wage pass-through adjusts smoothly: as the PUT margin shrinks, pass-through into w^P is dampened ($\eta^{P'} \leq 0$). Using

$$\eta^F = \frac{w^P}{w^F} \eta^P + \frac{\frac{t}{1-t} \overline{\text{PUT}}}{w^F} e_2, \quad (42)$$

and noting that both η^P and e_2 shrink in magnitude as t rises, we obtain that $\eta^{F'}$ is small/ambiguous. These wage terms enter as $\alpha^P \eta^{P'} + \alpha^F \eta^{F'}$ and do not overturn the negative PUT-attenuation term. Moreover, the $e_1^{P'}$ pieces combine to $(\alpha^P - \gamma)e_1^{P'}$ (since $-\gamma e_1^{P'}$ sits opposite $+\alpha^P e_1^{P'}$), which is positive but typically small. In short: higher t makes the key PUT margins less elastic, so the behavioral component lowers ETI.

8.3. Optimal Income Tax: Surplus Derivation

This appendix shows that every equilibrium object is a function of a single surplus wedge in (τ, t) -space. At any interior equilibrium the five key conditions are

$$\text{Firm FOC (indifference): } w^F = w^P + \frac{t}{1-t} \overline{\text{PUT}}, \quad (\text{A})$$

$$\text{MPL-wage (formal): } \phi'(L) = w^F, \quad L = L^P + L^F, \quad (\text{B})$$

$$\text{Worker FOC for PUT: } \tau = \theta \overline{\text{PUT}} g'(\theta \overline{\text{PUT}} l), \quad (\text{C})$$

$$\text{PUT labor market-clearing: } L^{D,P}(w^P, t, \overline{\text{PUT}}) = L^{S,P}(w^P, \tau, \overline{\text{PUT}}), \quad (\text{D}_P)$$

$$\text{Formal labor market-clearing: } L^{D,F}(w^F, t, \overline{\text{PUT}}) = L^{S,F}(w^F, \tau, \overline{\text{PUT}}). \quad (\text{D}_F)$$

I linearise these conditions around a given interior equilibrium

$$(\tau, t, \overline{\text{PUT}}, w^P, w^F, L^P, L^F),$$

and study small policy changes $(d\tau, dt)$. The argument proceeds in three steps: (i) linearise the five equilibrium conditions, (ii) derive the first-order responses of wages to $(d\tau, dt)$, and (iii) show that all equilibrium responses load on a single wedge $S(\tau, t)$.

8.3.1. Linearization of the five equilibrium conditions

Firm FOC (A). Total differentiation of (A) gives

$$dw^F - dw^P = \frac{\partial}{\partial t} \left(\frac{t}{1-t} \right) \overline{\text{PUT}} dt + \frac{t}{1-t} d\overline{\text{PUT}} \quad (43)$$

$$= \frac{\overline{\text{PUT}}}{(1-t)^2} dt + \frac{t}{1-t} d\overline{\text{PUT}}. \quad (\text{A-diff})$$

MPL-wage (B). Differentiating $\phi'(L) = w^F$ and using $L = L^P + L^F$,

$$\phi''(L)(dL^P + dL^F) = dw^F. \quad (\text{B-diff})$$

Worker FOC for PUT (C). Differentiating (C) with respect to τ and $P\bar{U}T$ gives

$$d\tau - \underbrace{\left[g'(\cdot) + \theta P\bar{U}T g''(\cdot) \right]}_{G > 0} dP\bar{U}T - \underbrace{\theta P\bar{U}T^2 g''(\cdot) dl}_{\text{Frisch elasticity term}} = 0. \quad (44)$$

We assume the intensive Frisch elasticity of hours is small, so in first-order terms we hold hours fixed, $dl \simeq 0$. This implies that most of the change in labor supply comes from switching between arrangements, not from adjusting hours. Then:

$$d\tau - G dP\bar{U}T = 0, \quad G \equiv \frac{\partial \tau}{\partial P\bar{U}T} > 0, \quad (45)$$

so

$$dP\bar{U}T = \frac{d\tau}{G}. \quad (\text{C-diff})$$

The explicit formula for G is not needed; it is only important that it is positive and evaluated at the initial equilibrium.

PUT labor market clearing (D_P). Define

$$H^P(w^P, t, \tau, P\bar{U}T) \equiv L^{D,P}(w^P, t, P\bar{U}T) - L^{S,P}(w^P, \tau, P\bar{U}T) = 0 \quad (46)$$

at equilibrium. Total differentiation gives

$$H_w^P dw^P + H_t^P dt + H_\tau^P d\tau + H_{P\bar{U}T}^P dP\bar{U}T = 0. \quad (47)$$

Define the net slopes (demand minus supply) at the equilibrium as

$$L_w^P = H_w^P, \quad L_t^P = H_t^P, \quad L_\tau^P = H_\tau^P, \quad L_{P\bar{U}T}^P = H_{P\bar{U}T}^P. \quad (48)$$

Then the linearized PUT market-clearing condition is

$$L_w^P dw^P + L_t^P dt + L_\tau^P d\tau + L_{P\bar{U}T}^P dP\bar{U}T = 0. \quad (D_P\text{-diff})$$

Formal labor market clearing (D_F). Similarly, define

$$H^F(w^F, t, \tau, P\bar{U}T) \equiv L^{D,F}(w^F, t, P\bar{U}T) - L^{S,F}(w^F, \tau, P\bar{U}T) = 0. \quad (49)$$

Total differentiation gives

$$L_w^F dw^F + L_t^F dt + L_\tau^F d\tau + L_{P\bar{U}T}^F dP\bar{U}T = 0, \quad (D_F\text{-diff})$$

By definition, L_w^P and L_w^F are net (demand minus supply) slopes with respect to wages, and $L_t^\bullet, L_\tau^\bullet, L_{P\bar{U}T}^\bullet$ capture the demand/supply shifts induced by t, τ , and $P\bar{U}T$.

So far there are five linearized equilibrium conditions:

$$(\text{A-diff}), \quad (\text{B-diff}), \quad (\text{C-diff}), \quad (\text{D}_P\text{-diff}), \quad (\text{D}_F\text{-diff}),$$

which jointly pin down the responses $(dw^P, dw^F, dP\bar{U}T, dL^P, dL^F)$ to $(d\tau, dt)$.

8.3.2. Wages as functions of the policy shocks

The worker FOC gives

$$dP\bar{U}T = \frac{1}{G} d\tau. \quad (50)$$

Substitute this into the firm FOC (A-diff):

$$dw^F - dw^P = \frac{P\bar{U}T}{(1-t)^2} dt + \frac{t}{1-t} \frac{1}{G} d\tau. \quad (51)$$

Now use the market-clearing conditions to express how wages respond to the policy shocks. Start from (D_P-diff):

$$L_w^P dw^P + L_t^P dt + L_\tau^P d\tau + L_{P\bar{U}T}^P dP\bar{U}T = 0.$$

Solve this for dw^P :

$$dw^P = -\frac{L_t^P}{L_w^P} dt - \frac{L_\tau^P}{L_w^P} d\tau - \frac{L_{P\bar{U}T}^P}{L_w^P} dP\bar{U}T. \quad (52)$$

Define the reduced-form slope coefficients

$$\beta_1 \equiv -\frac{L_\tau^P}{L_w^P}, \quad \beta_2 \equiv -\frac{L_t^P}{L_w^P}, \quad \beta_3 \equiv -\frac{L_{P\bar{U}T}^P}{L_w^P},$$

so that

$$dw^P = \beta_1 d\tau + \beta_2 dt + \beta_3 dP\bar{U}T. \quad (53)$$

Similarly, from (D_F-diff):

$$L_w^F dw^F + L_t^F dt + L_\tau^F d\tau + L_{P\bar{U}T}^F dP\bar{U}T = 0,$$

one obtains

$$dw^F = \gamma_1 d\tau + \gamma_2 dt + \gamma_3 dP\bar{U}T, \quad (54)$$

where

$$\gamma_1 \equiv -\frac{L_\tau^F}{L_w^F}, \quad \gamma_2 \equiv -\frac{L_t^F}{L_w^F}, \quad \gamma_3 \equiv -\frac{L_{P\bar{U}T}^F}{L_w^F}.$$

Next, eliminate $dP\bar{U}T$ using equation (50). Plugging (50) into (53)–(54) gives:

$$dw^P = \left(\beta_1 + \frac{\beta_3}{G}\right) d\tau + \beta_2 dt, \quad \equiv A_\tau d\tau + A_t dt, \quad (55)$$

$$dw^F = \left(\gamma_1 + \frac{\gamma_3}{G}\right) d\tau + \gamma_2 dt, \quad \equiv B_\tau d\tau + B_t dt. \quad (56)$$

Thus the four coefficients (A_τ, A_t, B_τ, B_t) are determined functions of the underlying slopes L^P, L^F and the PUT FOC parameter G .

Now impose the firm arbitrage condition from equation (51). Substituting (55)–(56) into (51) gives:

$$\underbrace{(B_\tau - A_\tau) d\tau}_{\text{coeff. on } d\tau} + \underbrace{(B_t - A_t) dt}_{\text{coeff. on } dt} = \frac{P\bar{U}T}{(1-t)^2} dt + \frac{t}{(1-t)G} d\tau.$$

Equating coefficients on $d\tau$ and dt ,

$$B_\tau - A_\tau = \frac{t}{(1-t)G}, \quad B_t - A_t = \frac{\text{P}\bar{\text{U}}\text{T}}{(1-t)^2}. \quad (57)$$

At this point, A_τ, A_t, B_τ, B_t are expressed in terms of the slopes (L^P, L^F) , the PUT FOC parameter G , and the equilibrium $\text{P}\bar{\text{U}}\text{T}$ and t .

8.3.3. A single surplus wedge in (τ, t)

The MPL condition (B-diff) links wages and employment:

$$\phi''(L)(dL^P + dL^F) = dw^F$$

Since L^P and L^F are themselves equilibrium objects, they must also have linear first-order responses to $(d\tau, dt)$. By the market-clearing conditions (D_P)–(D_F), their levels are determined by the same demand and supply primitives that generated the slopes L^P and L^F . Hence, for small perturbations $(d\tau, dt)$ around the initial equilibrium there exist reduced-form responses

$$dL^P = C_\tau^P d\tau + C_t^P dt, \quad dL^F = C_\tau^F d\tau + C_t^F dt, \quad (58)$$

for some coefficients $C_\tau^P, C_t^P, C_\tau^F, C_t^F$ that are functions of the same underlying slopes L^P, L^F and of the PUT FOC parameter G . Substituting these expressions into (B-diff) and using $dw^F = B_\tau d\tau + B_t dt$ gives:

$$\phi''(L)[(C_\tau^P + C_\tau^F) d\tau + (C_t^P + C_t^F) dt] = B_\tau d\tau + B_t dt \quad (59)$$

Then, matching coefficients gives

$$\phi''(L)(C_\tau^P + C_\tau^F) = B_\tau, \quad \phi''(L)(C_t^P + C_t^F) = B_t \quad (60)$$

and from equation (60) it follows that:

$$\frac{B_t}{B_\tau} = \frac{C_t^P + C_t^F}{C_\tau^P + C_\tau^F} \quad (61)$$

The coefficients $C_\tau^P, C_t^P, C_\tau^F, C_t^F$ are obtained by applying the implicit-function theorem to the same five-equation system (A)–(D_F) that determines the wage coefficients A and B . Hence they are functions of the same underlying primitives: the net slopes L^P, L^F , the PUT FOC parameter G , and the tax parameters $(\tau, t, \text{P}\bar{\text{U}}\text{T})$.

Substituting the reduced-form expressions for $C_\tau^P, C_t^P, C_\tau^F, C_t^F$ (together with (57)) into the ratio above generates that all terms involving labor-demand and labor-supply slopes L^P, L^F cancel. The remaining dependence on the primitives is

$$\frac{B_t}{B_\tau} = -\frac{1}{(1-t)^2}, \quad (62)$$

so the formal wage response can be written as

$$dw^F = B_\tau \left[d\tau - \frac{dt}{(1-t)^2} \right]. \quad (63)$$

An analogous computation shows that every other endogenous variable $X \in \{w^P, w^F, \text{P}\bar{\text{U}}\text{T}, L^P, L^F\}$ has the same policy direction, i.e.

$$dX = \kappa_X \left[d\tau - \frac{dt}{(1-t)^2} \right], \quad (64)$$

for some scalar κ_X evaluated at the equilibrium.

Since the vector $(1, -1/(1-t)^2)$ is a gradient, there exists a scalar function $S(\tau, t)$ such that

$$\partial_\tau S(\tau, t) = 1, \quad \partial_t S(\tau, t) = -\frac{1}{(1-t)^2} \quad (65)$$

Integrating with respect to τ and t gives

$$S(\tau, t) = \tau - \frac{t}{1-t} + C_0, \quad (66)$$

and dropping the irrelevant constant C_0 ,

$$S(\tau, t) = \tau - \frac{t}{1-t}, \quad dS = d\tau - \frac{dt}{(1-t)^2}. \quad (67)$$

Thus, all equilibrium objects are functions of this surplus wedge $S(\tau, t)$ rather than of τ and t separately:

$$dX = \kappa_X dS \quad (68)$$

8.4. ETI Estimation: Event Studies

I use event studies to complement my ETI estimates. These allow me to do two things: (i) test for parallel trends in the pre-period and (ii) see whether there is a discrete jump right when the policy takes effect.

I label the 2020–2021 change as Event A and the 2022–2023 change as Event B. Event A raises payroll (healthcare) tax rates for Agricultural Regime (AgR) firms; General Regime (GR) firms are unaffected. Event B applies only to large AgR firms in 2023; small AgR firms are unaffected. I estimate dynamic effects with monthly event time, using the month before the start of the event as the reference month.

To estimate the effects of Event A, I run the following regression for the period 2020–2022:

$$y_{it} = \alpha_i + \lambda_t + \sum_{s \neq -1} \beta_s \mathbf{1}\{t - g_i^A = s\} A_i + \varepsilon_{it}, \quad t \in [2020, 2022], \quad (69)$$

where $A_i = \mathbf{1}\{\text{AgR}\}$ takes the value of one for firms affected by Event A (the treatment, the Agricultural Regime firms). Controls are GR firms ($A_i = 0$). g_i^A is the first treated month (January 2021 for all $A_i = 1$). α_i are regime $\times$ size fixed effects (and I also include department FE in some specifications), and λ_t are month fixed effects. The coefficients β_s are dynamic DiD effects at event time s relative to $s = -1$:

$$\beta_s = [y_{it}(s) - y_{it}(-1) \mid A_i=1] - [y_{it}(s) - y_{it}(-1) \mid A_i=0].$$

To estimate the effects of Event B, I run the following regression only among firms in the Agricultural

Regime:

$$y_{it} = \alpha_i + \lambda_t + \sum_{s \neq -1} \theta_s \mathbf{1}\{t - g_i^B = s\} B_i + u_{it}, \quad t \in [2022, 2023], \quad (70)$$

where the sample is restricted to AgR firms. $B_i = \mathbf{1}\{\text{large AgR}\}$ takes the value of one for firms affected by Event B (large AgR firms), small AgR firms serve as controls ($B_i = 0$). g_i^B is the first month after Event B starts (January 2023 for $B_i = 1$). Here θ_s are dynamic effects of moving from the first to the second schedule, relative to $s = -1$, netting out contemporaneous changes for small AgR firms.

8.5. Implications for the Optimal Tax: Other Parameter Values

Table MA1: Optimal labor income tax under other parameter values (%)

	Workers alone	PUT, $t = 15\%$	PUT, $t = 20\%$	Reported wages true
Baseline ($\bar{g} = 0.6, g_\pi = 0, e_1 = 0.2$)	14.8	26.5	44.3	66.7
$\bar{g} = 0.5$	17.9	29.1	48.8	71.4
$\bar{g} = 0.7$	11.5	23.7	39.0	60.0
$e_1 = 0$	14.8	27.6	47.8	100.0
$e_1 = 0.4$	14.8	25.4	40.9	50.0
$g_\pi = 0.25$	14.8	23.6	42.0	66.7
All 18 combinations, range	11.5–17.9	19.8–30.2	33.6–52.0	50.0–100.0

Notes: Equation (33). Each row changes one parameter from the baseline; the last row covers every combination of $\bar{g} \in \{0.5, 0.6, 0.7\}$, $e_1 \in \{0, 0.2, 0.4\}$ and $g_\pi \in \{0, 0.25\}$. In every combination, the optimal tax is lowest when evasion is a decision of workers alone, rises with the corporate tax, and is highest when reported wages are taken as true. ETI: 2.3 in the first two columns, 0.75 in the third (Table 9), and e_1 in the fourth, where there is no fiscal externality; with $e_1 = 0$, a government that takes reported wages as true sees no response to taxes at all.