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Tax Evasion and the Minimum Wage

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ABSTRACT

Exploiting a change in reporting defaults and the implied audit threat in Hungary, we demonstrate that a substantial portion of employees and the self-employed reporting to earn the minimum wage have much higher earnings in reality. This can be seen from their sharp but temporary jump to the new reporting default, a twofold increase in reported earnings. Consistent with misreporting, the response is concentrated both spatially and by employer and the distribution of covariates around the threshold exhibits anomalies. Requiring individuals reporting to earn the minimum wage to pay higher taxes or ask for explicit exceptions increases reported earnings for some and decreases formal employment for others, suggesting a trade-off for taxation. We formalize the empirical findings in a model of minimum wage taxation where earnings underreporting around the minimum wage would justify a move towards higher taxation of those earnings, more aligned with a prevalent international practice.

JEL codes: H26, J31

Keywords: minimum wage, tax evasion, audit, Hungary

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Adócsalás és a Minimálbér

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ÖSSZEFOGLALÓ

Kihasználva az adórendszer és adóellenőrzés változásait, tanulmányunkban bemutatjuk, hogy a magánszektorban alkalmazottak és az egyéni vállalkozók körében a minimálbérre bejelentett dolgozók jelentős része valójában lényegesen többet keres. Ezt onnan látjuk, hogy a kétszeres minimálbérszabály bevezetésekor a korábban minimálbért jelentők jelentős részének a keresete átmenetileg a minimálbér kétszeresére ugrott fel. Az adócsalásra utal, hogy a kétszeres minimálbérszabályra való reakció mind térben, mind a foglalkoztatók között koncentrált, valamint egyéb megfigyelt egyéni jellemzők is anomáliákat mutatnak a kétszeres minimálbér szintje körül. A minimálbért jelentők magasabb adóztatása vagy a magasabb adózás alóli mentességnek az adóhivatalnál való kérelmezésének a megkövetelése azt eredményezi, hogy a bejelentett keresetek emelkedése mellett, ellentételező hatásként, a formális foglalkoztatás aránya is csökken. Az empirikus eredményeket egy munkakeresleti és adókerülési modell keretébe illesztjük. Modellünk fő eredménye, hogy a magasabb (adóztatott) minimálbér helyettesítője a hatékonyabb adóbehajtásnak, összhangban a nemzetközi gyakorlattal.

JEL: H26, J31

Kulcsszavak: minimálbér, adócsalás, adóellenőrzés

Tax Evasion and the Minimum Wage*

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Abstract

Exploiting a change in reporting defaults and the implied audit threat in Hungary, we demonstrate that a substantial portion of employees and the self-employed reporting to earn the minimum wage have much higher earnings in reality. This can be seen from their sharp but temporary jump to the new reporting default, a twofold increase in reported earnings. Consistent with misreporting, the response is concentrated both spatially and by employer and the distribution of covariates around the threshold exhibits anomalies. Requiring individuals reporting to earn the minimum wage to pay higher taxes or ask for explicit exceptions increases reported earnings for some and decreases formal employment for others, suggesting a trade-off for taxation. We formalize the empirical findings in a model of minimum wage taxation where earnings underreporting around the minimum wage would justify a move towards higher taxation of those earnings, more aligned with a prevalent international practice.

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1 Introduction

Why would we tax the minimum wage? Gross minimum wages can be twice as high as the net in some countries. Even with quite inelastic labor demand, one would think that a lower tax burden could boost employment with the same take-home pay. This paper presents evidence for one potential justification for high and taxed minimum wages: they recover some tax revenue from higher earners who underreport their income.

As long as firms can hire some of their workers informally, the minimum wage is a critical threshold: the least reported pay registered employees can get away with. Registration lowers firms' risk of getting caught relative to having unreported employees. It is also the lowest wage that a worker can legally report and still qualify for social security benefits or health insurance. This suggests that firms and workers may collude in substantial underreporting of earnings specifically at the minimum wage and that many workers who declare the minimum wage may be making more.

In this paper, we demonstrate that misreporting is an empirically relevant phenomenon even in a high-income country, with implications for the optimal taxation of the minimum wage. We do so by exploiting a unique policy in Hungary that introduced a new audit threshold at twice the amount of the monthly minimum wage. Between late 2006 and 2010, firms were required to pay social security contributions based on at least twice the amount of the monthly minimum wage or ask for an exception. In the latter case, they understood to face higher probabilities of audit from tax authorities. We examine how firms' reporting behavior and the employment of affected workers changed. In our panel, we can track workers over time, and examine at the individual level whether someone was moved by this regulation, the so-called "double minimum wage rule."

We find that firms responded to the new threshold in ways that are consistent with substantial underreporting of earnings precisely at the minimum wage. Specifically, we find that 10.5% of private-sector employees and 19.2% of the self-employed who declared the minimum wage before the reform reported monthly earnings exactly twice the minimum soon after. This phenomenon suggests that they earned extra off the books prior to the reform. In the years after the initial introduction of the new threshold, the concentration of earnings at the threshold decreases, most likely because of firms' changing perception of the audit threat.

We document other patterns consistent with previous underreporting. First, there is no response

by public sector employees to the introduction of the new threshold. Second, the response is more pronounced in the industries most prone to tax evasion. Third, the response is concentrated in small and domestic companies and is larger for less productive companies. Fourth, individuals who respond look very different from individuals who report just below or just above the threshold on a variety of measures. Fifth, the response is concentrated within firms. Sixth, the response is concentrated within specific geographic areas.

After describing changes in wage reporting consistent with previous underreporting, we show that in response to the policy some workers exit formal employment. Specifically, we show that when the government introduced the reform, workers who reported earning the minimum wage were more likely to leave formal employment than workers who reported low earnings above the minimum wage. We find that around 2% of private sector employees exit formal employment as a consequence of the reform. This exit response leads to a loss in tax revenue, in contrast with the higher tax revenue from those who "comply" by reporting higher earnings than before. This implies a trade-off for governments taxing these low incomes: a broader tax base as some workers and firms formalize more of their income but also a concurrent loss as others go entirely informal.

In the last part of the paper, we formalize this observed trade-off in our model. Abstracting away from the labor supply decision, surplus producing jobs will legitimately bunch at the minimum wage and thus mask misreporting also constrained by the coinciding enforcement threshold. The value of raising the minimum wage is a function of the density of the skill distribution as well as social welfare weights. However, weaker enforcement, a lower audit probability above the minimum wage, raises the value of a minimum wage hike under fairly general conditions. Enforcement, which is presumably costly, is thus a substitute for a higher minimum wage.[1]

Related Literature. Our work contributes to the literature on tax compliance and evasion, including recent work on audit threats (Kleven et al., 2011; Best, 2014; De Andrade, Bruhn and McKenzie, 2014; Hashimzade, Myles and Rablen, 2016; Bérgolo et al., 2017; Almunia and Lopez-Rodriguez, 2018; Di Gregorio and Paradisi, 2019; Choudhary and Gupta, 2019) and other policies

[1]Strictly speaking, governments usually tax annual income and not wages or even earnings, and we do not mean to use these words interchangeably. That said, in countries with individual taxation, stable incomes throughout calendar years, and few deductions or credits, many minimum wage earners pay similar and predictable taxes after their labor income. Some countries routinely report net minimum wages from these implied taxes, which we also report in our Table 1.

that encourage formalization and compliance (de Mel, McKenzie and Woodruff, 2013; Pomeranz, 2015; Naritomi, 2019; Kumler, Verhoogen and Frías, 2020).[2] We provide evidence on a policy, a mixture of presumptive taxation and a targeted audit threat, that can recover some tax revenue lost to misreporting when various considerations limit the set of possible policies and targeting tools.

We also contribute to the literature on informal employment and taxation (Kuehn, 2014; Meghir, Narita and Robin, 2015; Gerard and Gonzaga, 2016; Rocha, Ulyssea and Rachter, 2018; Ulyssea, 2018).[3] Using population-wide administrative data, we are able to track workers as they reported earnings increase, but also when they exit from formal employment. Our work suggests that tax enforcement may generate trade-offs for informality: it can formalize the earnings of some workers, while other workers' earnings will become entirely informal.

Our results on reporting responses to the double minimum wage rule allow us to measure underreporting around the minimum wage (Reizer, 2011; Elek, Köllő, Reizer and Szabó, 2012).[4] Our results indicate that in addition to increases in reported earnings by some workers previously reporting the minimum wage, other workers may opt out of formal employment. All this builds towards a pragmatic evaluation of minimum wage levels and the tax treatment of corresponding earnings.[5] The well-known result of Lee and Saez (2012) is that under perfect competition and efficient rationing of jobs the coexistence of a minimum wage with a positive tax rate on low-skilled work is Pareto inefficient.[6] At the same time, a substantial tax burden falls on minimum wage earners in many OECD countries (OECD, 2007). Our findings suggest that the revenue recovered from higher earners who misreport their earnings could partly rationalize taxing the minimum wage.[7]

The remainder of this paper proceeds as follows. We begin in Section 2 by providing background on the Hungarian tax system and the double minimum wage rule. Section 3 reviews bunching at

[2] See Andreoni, Erard and Feinstein (1998) and Slemrod (2019) for comprehensive reviews of the literature on tax compliance and enforcement.

[3] The informal economy and pay misreporting is sizable not only in low- and middle-income countries but in the high-income countries of Central and Eastern Europe, where some estimates put the size of the informal economy to 20% of GDP. (Williams and Padmore, 2013; Williams, 2013; Paulus, 2015).

[4] Informal employment can also evade the minimum wage regulation itself. Clemens and Strain (2020) argue that subminimum wage payments are prevalent even in the American low-wage labor market.

[5] For recent evidence on the effects of minimum wage increases, see Bossavie, Acar and Makovec (2019), Cengiz, Dube, Lindner and Zipperer (2019), Harasztosi and Lindner (2019), and Dustmann et al. (2020).

[6] Lavecchia (2020) motivates minimum wages accompanying optimal but second-best non-linear income taxes as a relief on low-skilled labor market tightness above socially optimal levels because of a search congestion externality or constrained optimal redistribution in the tax system.

[7] See Tonin (2011) and Tonin (2013) for earlier work on the minimum wage and tax evasion.

enforcement thresholds, motivating our empirical strategy. In Section 4, we describe the data used. Section 5 summarizes our methods and empirical framework. Section 6 presents our results. Section 7 presents a model of taxation of the minimum wage when underreporting is a concern at this point in the wage distribution. Finally, Section 8 concludes.

2 Background

2.1 Institutional Context

Hungary has long had a legal minimum wage. The minimum wage is mostly discussed as the monthly minimum for full-time workers, but proportional amounts are set for weekly and hourly pay as well. After a large 2001 raise, the gross minimum wage remained relatively stable, while the net minimum wage fluctuated along with changes in the tax system. In real dollar terms, the net minimum wage rose 3.4% per year on average over this period. Income is taxed on an annual basis throughout the period, so our discussion of the tax treatment of the minimum wage assumes full-time, full-year employment at the prevailing minimum wage. We also abstract from tax deductions and credits. Gross and net monthly minimum wages and the Guaranteed Minimum Wage for skilled jobs assumed to require a high school diploma introduced in 2006 are tabulated in Table 1.

Labor income is taxed heavily in Hungary. Between 2003 and 2011, the years covered by our data, the average tax wedge varied between 46% an 55%, without any major reforms in the taxation of labor income. In 2006 for instance, Hungary had the third largest average tax wedge among 36 OECD countries (OECD, 2019). Labor income taxes include a payroll tax (in 2006, 18% on the first 1,550,000 HUF, 36% above), social security contributions paid by the employee (15.5% in 2006), and social security contributions paid by the employer (altogether 30% in 2006). In Hungary, the tax wedge on minimum wage earners is high and close to the average tax wedge. Table 2 shows the payroll tax and social security contribution rates by year.

Two major forms of informal employment have been documented in Hungary. The first is undeclared work, when no employment relationship is reported to the tax authority, and consequently neither the employer, nor the employee pays any taxes. Based on discrepancies between pension fund microdata and survey evidence, in the early 2000s 16-17% of employees were undeclared (Elek, Scharle, Szabó and Szabó, 2009*b*; Benedek, Elek and Köllő, 2013). The second form is wage

underreporting, when an employment relationship is reported to the tax authority but reported earnings are substantially lower than true earnings. Since some taxes are paid on this work, this form of employment is more costly than undeclared work, but it also offers certain advantages for both employers and employees. Employers may appear more legitimate to the tax authority and they may be able to rely more on their employees since a formal employment contract exists. Employees can also enjoy some protections of a formal work contract and reporting some earnings qualifies them for a wide set of benefits, including public health insurance, disability insurance, unemployment insurance, and pensions. A common form of "grey" employment in Hungary is the reporting of wages at the minimum wage while supplementing earnings in cash (Elek, Scharle, Szabó and Szabó, 2009*a*; Elek, Köllő, Reizer and Szabó, 2012).[8]

2.2 Double Minimum Wage Rule

In order to reduce wage underreporting, Hungary introduced a so-called "double minimum wage rule" in 2006. This rule required employers to pay social security contributions on at least twice the minimum wage for an employee. Employers could ask for an exemption from this rule on a special form if their true wages were lower than twice the amount of the minimum wage, indicating the exact amount of wages. This could then increase the probability of a tax audit. If the reported wage was below twice the the amount of the minimum wage but no exemption was requested then the employer had to pay the employers' social security contributions based on twice the amount of the minimum wage, plus also had to pay the employees' social security contributions for the difference between the reported wage and twice the amount of the minimum wage. This rule incentivized employers to either request an exemption from the rule or to report at least twice the amount of the minimum wage towards tax authorities. The double minimum wage rule applied to both private sector employees and the self-employed. The rule was in effect between September 1, 2006 and December 31, 2010.

The double minimum wage rule can be considered presumptive taxation. A presumed tax base is a substitute for a desired tax base; the presumed tax base is derived from items that are easier to monitor. Presumptive taxation exists whenever the legislator is using one tax base in order to approximate another (Slemrod and Yitzhaki, 1994; Yitzhaki, 2007). The double minimum wage

[8] We discuss some reported audit statistics of the Tax Authority in Appendix B.

rule does not rely on additional observable items, but it "presumes" that the taxpayer's earning is no less than twice the minimum wage, unless the taxpayer proves otherwise.[9]

3 Bunching at Enforcement Thresholds

This section introduces a model of labor demand that generates bunching both at enforcement thresholds (from inframarginal evasion) and the minimum wage (from supramarginal efficiency wages).

Employer Optimization In partial equilibrium, firms post, create, fill each job to maximize their profit.[10] Abstracting away from the demand curve and input supply curves the firms face, employers (or the self-employed) will set a worker's efficiency wage w,[11] and evasion level e to maximize profit $V(w, e \mid \theta)$.

$$\max_{w,e} V(w, e \mid \theta) = f(w \mid \theta) - w - \tau \cdot \underbrace{(w - e)}_{\text{Declared Earnings}} - \underbrace{\rho \cdot p \cdot \tau \cdot e}_{\text{Expected Audit Cost}} - \underbrace{g(e)}_{\text{Manipulation Cost}} \tag{1}$$

where $f()$ is the production fuction for a firm (job), e is the amount of manipulation in earnings, θ is a productivity parameter, p is the audit probability the firm faces, τ is the tax wedge on declared earnings, and ρ is the recovery rate on misreported earnings if caught.

The production function defines input demand by the first-order conditions

$$f_w(w \mid \theta) = (1 + \tau), \tag{2}$$

$$\tau(1 - \rho p) = g'(e). \tag{3}$$

For a well-behaved f, these also define the implicit function for $\partial w / \partial \theta$.

Assumption 1. *For the production and evasion cost functions, assume continuous twice differentiability with $f'' < 0$ and $g'' > 0$, for decreasing marginal product and increasing marginal*

[9] Bulgaria introduced a similar rule in 2003, called the minimum insurance income thresholds, to curb the widespread practices of insuring employees at the level of the statutory minimum monthly wage instead of the actual wage (Pashev, 2006).

[10] This framework neglects labor-labor substitution in larger firms.

[11] We do not distinguish between prices and quantities of output and labor (effective hours), everything could be isomorphic between different compositions of $p(y) \cdot y$ and $w(l) \cdot l$.

costs.

Without loss of generality, order the productivity types such that the (unconstrained) marginal value product of labor is strictly increasing in productivity θ*:* $\partial^2 f/\partial w \partial \theta > 0$*.*

Furthermore, assume that $g(0) = 0$ *and* $g'(0) = 0$*, thus a little evasion is always worth it unless other constraints forbid it.*

3.1 Static Bunching at Enforcement Thresholds

This environment generates an excess mass of employment at reported income levels where enforcement changes discontinuously, as inframarginal evaders end up reporting the threshold amount for a range of jobs.

Assume p dropping from p_0 to $p_1 < p_0$ at some declared earnings threshold $w - e = D$. So audit probability p is decreasing, i.e.

$$p = \begin{cases} p_0 & \text{if } w - e < D \\ p_1 & \text{if } w - e \geq D \end{cases} \tag{4}$$

For unconstrained cases, equation (3) defines optimal evasion by inverting a well-behaved (and strictly increasing) g' function, which we can label as $E()$, which is also strictly increasing.

Then for low productivity firms far from D, e is constant at $E(\tau - \rho p_0 \tau)$, and production is at its unconstrained optimum as long as

$$w - E(\tau - \rho p_0 \tau) \leq D. \tag{5}$$

As the (unconstrained) marginal value product of labor is strictly increasing in productivity θ, this is satisfied for all $\theta < \theta_0$ if there exists a level θ_0 for which

$$w(\theta_0) - E(\tau - \rho p_0 \tau) = D. \tag{6}$$

Here we let a univariate $w()$ denote the dependence of the unconstrained solution of equation (2) on productivity only.

For firms with high enough productivity, $e = E(\tau - \rho p_1 \tau)$ as long as (by the same monotonicity)

$\theta_1 < \theta$ where

$$w(\theta_1) - E\left(\tau - \rho p_1 \tau\right) = D. \tag{7}$$

In between, for $\theta \in [\theta_0, \theta_1]$ the firm will produce and evade just enough that $w - e = D$. The exact mix of suboptimal production and intermediate evasion depends on the marginal cost of each.[12]

For a continuous distribution of θ with c.d.f. $H(\theta)$, this implies the mass of $H(\theta_1) - H(\theta_0)$ bunching at the enforcement threshold D. This is the mass missing from the left of the threshold D in a world without frictions and noise.

We can check for consistency in $\theta_0 < \theta_1$, which again follows from the (arbitrary) ordering of the marginal value product of labor to increase in θ, as $w(\theta_0) - E\left(\tau - \rho p_0 \tau\right) = w(\theta_1) - E\left(\tau - \rho p_1 \tau\right)$ and $E\left(\tau - \rho p_0 \tau\right) < E\left(\tau - \rho p_1 \tau\right)$ and $w(\theta_0) < w(\theta_1)$.

3.2 Shifts in Bunching

We can easily extend the situation to two thresholds, an extremely well enforced lower threshold M and an initially ineffective new threshold D.

Initially, $p_0 = p_1$ but for reported earnings below some $M < D$, $p_M \gg p_0$ (and if $p_M \leq 1$ would bind, allow for $\rho_M \gg \rho$ as additional punitive fines). Analogously to the previous argument, only firms with $\theta > \theta_M$ will report earnings above M, where

$$w(\theta_M) - E\left(\tau - \rho p_1 \tau\right) = M. \tag{11}$$

If p_0 rises for reported earnings in $[M, D]$, the bunch appears as under the previous point and

[12] If the shadow price of relaxing the $w - e = D$ constraint is the Lagrange multiplier λ, the following first-order conditions characterize the constrained optimum when this condition binds:

$$f_w(w \mid \theta) - (1 + \tau) + \lambda = 0, \tag{8}$$
$$-\tau(1 - \rho p) - g'(e) - \lambda = 0. \tag{9}$$

This links the marginal value product of labor (MVPL) to the tax rate and the costs of evasion:

$$f_w(w \mid \theta) = 1 + 2\tau - \rho p \tau + g'(e). \tag{10}$$

the bunching at M becomes smaller. Some evaders are pushed off M with a new productivity cutoff

$$w(\theta'_M) - E\left(\tau - \rho p_0 \tau\right) = M. \tag{12}$$

Again, for a higher p, the lower implied e necessitates a lower θ'_M with the lower marginal value.

Assumption 2. *M is high enough to leave θ_M to the right of the mode of its (assumed) unimodal distribution H.*

Proposition 1. *Equilibrium evasion (shading) is lower with a higher probability of getting caught, $E\left(\tau - \rho p_0 \tau\right) = e_0 < E\left(\tau - \rho p_1 \tau\right) = e_1$. Thus the real earnings behind any specific reported earnings $\tilde{w} = w - e_0 \in [M, D]$ is higher than before with stricter enforcement (with $w(\theta) = \tilde{w} + e_1$ for the same $\tilde{w}$). Thus the density of those observed earnings changes to the density of higher productivity. The density $h(\theta)$ is strictly decreasing over $\theta \in [M, D]$ already, and densities fall after stricter enforcement ($p_0 > p_1$) comes into effect. Also, the observed density of reported earnings will drop to 0 below D, for productivities higher than the new marginal buncher θ_0.*

Would the extra mass at D be a lower bound on the prior extra mass at M? Not surprisingly, this is somewhat ambiguous — with very harsh enforcement ($\rho_0 p_0 \gg \rho_1 p_1$, $e_0 \ll e_1$) and a large $D \gg M$, much of the bunching at D would come from the mass previously spread out between M and D and not necessarily bunching at M. Figure 1 illustrates the impact of stricter enforcement over $[M, D]$.

3.3 Bunching at a Threshold that is also the Minimum Wage

In practice, M is a well-enforced threshold on enforcement as it is also a legal minimum on remuneration. We can make both constraint ($M \leq w$)[13] and the participation constraint ($V \leq 0$) explicit (with respective shadow prices μ and ν).

In Appendix Section A.1, we derive how these constraints partition the parameter space into unconstrained evaders (Θ_1), bunching evaders (Θ_2) and bunching true minimum wage employers (Θ_3), as illustrated in Figure 2. The cutoff levels of productivity, whose shifts are key to the welfare

[13] The $w - e \geq M$ enforcement constraint is equivalent to non-negative evasion ($e \geq 0$) with an effective minimum wage. With neither constraint, you get bunching at M without enforcement reasons, but not purely from the distorted efficiency wage decision but also people overreporting pay. Instead of this unrealistic scenario, we only discuss the minimum wage as two constraints in one.

analyses in Section 7, are denoted by the corresponding lower-case letters: θ_4, θ_{32}, and θ_{21}. For the intuitive and empirically relevant ordering of these cases, the derivation makes use of the following additional assumption.

Assumption 3. *For the sake of empirical relevance, assume that the marginal firm with zero profit is one that barely pays the minimum wage without shading (or would pay even worse than the minimum and misreport better pay if this were allowed). This assures that evaders and truthful reporters both bunch at the reported minimum wage, which we consider both empirically relevant and more interesting for enforcement (otherwise all bunchers would reveal themselves to evade with no need for elaborate research designs).*

4 Data and Sample

We use an administrative panel dataset that brings together information on earnings, occupations, benefit receipt, healthcare spending, and other domains for a random 50% sample of the Hungarian population for years 2003–2011.[14] Since our focus is on the working age population, we restrict the sample to individuals aged 18–65.

4.1 Employment and Worker Characteristics

We observe monthly employment and earnings at the individual-firm level, as well as monthly data on benefit take-up. The earnings and labor market status indicators originate from the pension authority. These records are in effect used in the calculation of pension benefits after retirement. An individual is defined to be formally employed if the pension authority records any type of employment or self-employment on the 15th of the given month. Although labor market status and earnings are observed at the monthly level, due to data limitations (some of the earnings are smoothed within a job spell), we keep data from only a representative month (March) for each year. We drop person-year observations for which an individual holds multiple jobs. We observe gross earnings, which include all earnings that enter pension benefit calculations. We do not observe

[14] The dataset was constructed by selecting a random 50% sample (for privacy reasons) of the Hungarian population aged 5–74 in 2003 and following this initial sample until 2011. Inclusion in the dataset is effectively random as individuals with certain days of birth are included. Sample attrition might arise from emigration or death, the latter of which we record directly, but neither is particularly relevant for our study sample.

actual taxes paid by firms or workers, nor capital income.

We use several individual-specific variables, including age, gender, initial residence, social security benefits received (if any) and soccupation. Age, gender and residence come from a 2003 snapshot of the health insurance fund data; all labor market data come from the pension administration. From occupations, we impute skill levels by imputing the median education level of employees of the same occupation code as observed in the Labor Force Survey of the Central Statistical Office of Hungary. Area of residence is observed only in 2003, and not updated.[15] The data originating from the pension administration allow us to separate employment by sector; we divide workers into three groups: private sector employees, public sector employees, and the self-employed.[16] We restrict the group of the self-employed to individuals whom we observe to work in firms with observed size of one (70% of all self-employed). Thus, our analysis excludes freelancers and contractors who are not employees at a firm but who work in a firm which has two or more observed workers. Table 3 shows summary statistics for our sample of workers by sector.

An important limitation of our data is that earnings are smoothed within employment spells and calendar years. Specifically, employment spells are cut into calendar years and average within-spell, within-year earnings are reported. For example, if an individual remained in the same job throughout the year, then we observe her total annual earnings in that job divided by 12. If she remained in the job for several years, then we observe this measure specifically for each year. If she changed jobs within the year, then we observe separate spells for her jobs.[17] Because of this smoothing and the double minimum wage rule coming into effect in September 2006, people shifting from the minimum wage to its double are observed to earn between the two (the weighted average) throughout 2006 (including in March, the representative month we use). This data limitation guides our decision to exclude 2006 from most of our analyses, and instead focus on wage distributions in 2005 and 2007 and transitions between the minimum wage and the double minimum wage between 2005 and 2007.

[15] Cross-county migration can be approximated from 10-year census data. Over the 10-year period between 2001 and 2011, approximately 15% of the population moved between counties (Lakatos, L. Rédei and Kapitány, 2015).

[16] These sector definitions are consistent over years 2003-2009, less so for years 2010-2011, due to changes of definitions in the baseline data. We exclude from the group of private sector employees those who work at firms in which the ownership rate of the government is above 50% or where we observe in any year more than 10 public sector employees. Public sector employees are public servants whose earnings are regulated by the government, including teachers, physicians and civil servants, among others.

[17] We also observe separate records for contemporaneous employment spells with multiple employers, but exclude workers who have more than one employer at the same time.

4.2 Firm Characteristics

Tax authority data on firm-specific indicators are available only for larger firms (with double-entry bookkeeping).[18] Based on this, we see ownership (foreign versus domestic), sector and industry, firm size, net revenues, the total wage bill, gross value added, tangible assets and material costs. The revenue and cost indicators are annual measures, corresponding to a calendar year. Using these indicators, we calculate total factor productivity (TFP) as the sum of fixed effects and residuals from a firm level regression of the log of net revenue regressed on log costs of labor, capital and materials. Since the calculated TFP is based on the tax authority's firm-level records, it is not affected by sampling noise in our 50% sample. For our analyses, we use the observed number of workers in a firm because this can be calculated for all firms, regardless of the availability of firm-specific indicators from the tax authority. By our definition, self-employed individuals work in firms with observed size of one. Table 4 shows summary statistics for private-sector firm characteristics.[19]

5 Empirical Framework

In our analyses, we use the introduction of the double minimum wage rule in 2006 to provide evidence on the underreporting of earnings at the minimum wage, and to estimate the impact of the rule on reported earnings and formal employment. In this section, we discuss our empirical strategy.

5.1 Wage Bin Definitions

Throughout our analyses, we use two bin definitions to partition the earnings distribution. Where possible, we define absolute bins of size 5,000 HUF (≈$17). The advantage of these bins is that they are transparent and have the same absolute magnitude in each year. We also view them as relatively narrow: 5,000 HUF corresponds to 6-10% of the minimum wage in this period.[20] In order to facilitate cross-year comparison though, we also define relative wage bins. The lower end of

[18] Double-entry bookkeeping is compulsory for firms with annual income above 50 million HUF (approximately $160 thousand).

[19] In our matched employer-employee data, to each worker a firm identifier is attached. When analysing firm-level characteristics in the private sector, we first restrict the sample to the private sector employees (thus exclude the self-employed, freelancers and contractors) and then do the analysis on the so remaining subsample of firms. Therefore, those firms are excluded which do not employ any private sector employees.

[20] In Section 6.3, we also examine the robustness of our main results about wage reporting around the double minimum wage using a relative band of 95-105% around the annual level of the double minimum wage.

the first bin is the monthly minimum wage, the upper end of the first bin is 110% of the monthly minimum wage in years 2003-2005 (before the introduction of the guaranteed wage minimum), and the guaranteed wage minimum in years 2006-2011. Bins 2-6 are of equal width, the top of bin 6 equals the double minimum wage. Thus, the width of a bin equals around 18% of the monthly minimum wage. Bins 7-11 have the same width, the lower end of bin 7 equals the double minimum wage. Intervals 1-11 are left-closed and right-open. Finally, bin 12 is open ended, including all earnings at or above around three times the monthly minimum wage. The advantage of using relative wage bins is that they allow for cross-year comparison in a way that makes the wage bins follow the minimum wage. Fixed-width bins would lead to substantial narrowing over time in relative terms, since the gross minimum wage was 56% percent higher in 2011 than in 2003.

We do not observe hours worked, therefore part-time workers appear to have monthly earnings below the monthly minimum wage. We do not exclude them because we are unable to exclude part-time workers earning above the minimum wage.

5.2 Underreporting of Earnings at the Minimum Wage

Descriptive Evidence. The first set of analyses we present relies on the cross-sectional distribution of earnings before and after the introduction of the double minimum wage. We divide monthly earnings into 5,000 HUF (≈$17) bins and show histograms of the earnings distribution before (2005) and after (2007) the introduction of the double minimum wage rule, separately for private sector employees, the self-employed, and public sector employees. We start the bins at zero and censor the distribution at 300,000 HUF (≈$1,000) which is almost five times the minimum wage. In addition to this cross-sectional evidence, we exploit the panel nature of the data to directly analyze transitions of workers between different wage levels. We estimate two-year transition probabilities between each pair of wage bins.[21]

In our heterogeneity analyses, we focus on transitions from reporting earnings at the minimum wage in 2005 to reporting double the minimum wage in 2007. We calculate the percent of workers who transition by worker characteristics (gender, age, and skill level), firm characteristics (ownership, size, and industry), and total factor productivity as a measure of firm quality. We also break down

[21] We analyze two-year transition probabilities to account for the problem of smoothed earnings in 2006 discussed in Section 4.1.

these transition rates by 174 districts of Hungary, weighted by population, and analyse the relation between the district-specific transitions among private sector employees and the self-employed.

Regression Framework. Building on our descriptive results, we estimate event study regressions which describe the evolution over time of the probability of earning at the double minimum wage (DMW) among private sector employees and the self-employed, relative to public sector employees. Our estimating equation is

$$DMW_{it} = \beta_0 + \sum_{t \neq 2006} \beta_{1t} PE_{it} + \sum_{t \neq 2006} \beta_{2t} SE_{it} + \alpha_E + \tau_t + \varepsilon_{it} \tag{13}$$

where i indexes workers, PE_{it} is an indicator for private sector employees, SE_{it} is an indicator for the self-employed, α_E are sector fixed effects (public-sector employee, private-sector employee, or self-employed), and τ_t are year fixed effects. The coefficients of interest are β_{1t} and β_{2t}, the differential change between private sector employees or the self-employed and public sector employees in the likelihood of reporting earning the double minimum by year. In all our regressions, we cluster standard errors at the firm level.

In addition, we also estimate a constant treatment effect difference-in-differences version of this regression, essentially pooling all years before and after treatment:

$$DMW_{it} = \beta_0 + \beta_1 PE_{it} \times Post_t + \beta_2 SE_{it} \times Post_t + \alpha_E + \tau_t + \varepsilon_{it} \tag{14}$$

where we use the same notation as in equation (13) and $Post_t$ is an indicator for the post-period (years 2007-2010). We exclude year 2011 from this regression because the double minimum wage rule was no longer in effect by then. The coefficients of interest are β_1 and β_2, the differential change between private sector employees or the self-employed and public sector employees in the likelihood of reporting earning double the minimum between the pre and post period.

Identification. Our estimation relies on standard difference-in-differences assumptions. For the β_{1t} (β_{2t}) to represent a valid estimator of the impact of the double minimum wage rule on the share of private sector employees (the self-employed) who report earning the double minimum wage, we require that the evolution of the share of public sector employees who report earning the double

minimum wage be a valid counterfactual for the share of private sector employees and self-employed who report earning the double minimum wage, absent the introduction of the double minimum wage rule.

The only other contemporaneous policy change that we are aware of that would affect the overall distribution of wages in the sectors differently is the introduction of the guaranteed minimum wage for skilled jobs assumed to require a high school diploma. But we are not aware of any changes that would affect the distribution of wages specifically at the double minimum wage, including policies that would affect the three sectors diferentially. There are also unlikely to be any spurious wage dynamics that would affect the distribution of wages specifically at this point differentially in the three sectors.

We provide several pieces of evidence that suggest that share of public sector employees who report earning the double minimum wage would be a good counterfactual for the same shares in the private sector and among the self-employed, absent the introduction of the double minimum wage rule. First, in Figure 3, we observe no bunching at the double minimum wage or at any other point in the wage distribution among public sector employees either before or after the introduction of the double minimum wage rule. Second, when we move from the cross-section to tracking people as they move between different wage bins in Figure 4, we find that the two-year earnings dynamics of public sector employees appears fairly symmetric (moving from bin i to bin j has about the same probability as moving from bin j to bin i) both before and after the reform. Indeed, both before and after the reform, most public sector workers' earnings are stable on a two-year time horizon. Third, looking at trends in the share of public sector workers reporting to earn the double minimum wage in Figure 5, there are no changes in the share of public sector employees who report earning the double minimum wage either before or after the introduction of the double minimum wage rule. Fourth, looking at the observable characteristics of workers who report earning the double minimum wage in Figure 7, there are no anomalies in public sector workers' wage distribution at the double minimum wage, either before or after the introduction of the double minimum wage rule. Fifth, addressing the concern that the double minimum wage rule could have affected wage dynamics among public sector employees through exits from formal employment (another outcome we examine below), Figure 10 shows that the introduction of the double minimum wage rule was not associated with any changes in exit from formal employment among public sector workers.

5.3 Impact on Formal Employment

Descriptive Evidence. The first approach we take to analyzing the impact of the reform on formal employment shows the evolution over time of the probability of leaving formal employment for workers earning the minimum wage and for workers in the three relative wage bins (Bins 2-4) immediately above the minimum wage, separately for private sector employees and public sector employees. For this analysis, comparisons across relative wage bins are necessary because macroeconomic trends have a considerable impact on employment as it is apparent during the Great Recession in our figures and this impact is differential across sectors. There are very few self-employed in wage bins 2-4, therefore we cannot include the self-employed in this analysis.

Since in this analysis, we compare workers reporting their earnings, we need to account for a specific problem caused by the smoothing of wages within job spells and calendar years discussed in Section 4.1. Recall that due to this smoothing and the double minimum wage rule coming into effect in September 2006, people shifting from the minimum wage to its double are observed to earn between the two (the weighted average) throughout 2006. This means that people who change their reported earnings from the minimum wage to the double minimum wage in September (or any other months during 2006) are not included among the observed minimum wage earners in March 2006. The problem for our analysis is that long-employed people shifting from the early-2006 minimum wage to its late-2006 double are likely to have a lower counterfactual probability of leaving their steady job by March 2007 than those who report the minimum wage throughout the year. This means that indepently from the double minimum wage rule, those observed to report the minimum wage for their entire spell in 2006 (whenever it ended) are much more likely to leave formal employment by next spring than those observed to report earning above the minimum wage. Hence, our naive estimates of the impact of the double minimum wage rule on exit from formal employment among observed minimum wage earners would likely overstate the effect.

To get around this issue, we estimate the impact of the double minimum wage rule on formal employment using earnings in December of year t, and looking at the rate of formal employment in January of year $t+2$ (i.e. 13 months later). Thus our estimates are not biased by our differential mismeasurement of earnings in 2006 as we analyze the probability of leaving formal employment between December 2005 and January 2007 by reported wage bin in December 2005. This approach

likely underestimates the true annual effect because we miss spells starting in 2006.[22]

Regression Framework. Building on our descriptive results, we estimate event study regressions which describe the evolution over time of the probability of leaving formal employment among those earning the minimum wage 13 months before relative to those earning in one of the relative wage bins just above, separately for private-sector employees, and public-sector employees. We cannot conduct this analysis for the self-employed because of the very low number of self-employed reporting earnings above the minimum wage bin. Our estimating equation is

$$Exit_{it} = \beta_0 + \sum_{t \neq 2006} \beta_t MW_{i,t-1} + \alpha_B + \tau_t + \varepsilon_{it}, \tag{15}$$

where i indexes workers, $MW_{i,t-1}$ is an indicator for being in the minimum wage bin (vs. the control wage bin) 13 months before, α_B are wage bin fixed effects (minimum wage vs. control), and τ_t are year fixed effects. The coefficients of interest are β_t, the differential change between workers reporting to earn the minimum wage and workers reporting to earn just above the minimum wage in the likelihood of exiting formal employment by year.[23]

We also examine heterogeneous responses, re-estimating Equation (15) and splitting the sample by worker characteristics (gender, age, and skill level), firm characteristics (ownership, size, and industry), and a measure of firm quality (total factor productivity).

Identification. Our estimation again relies on standard difference-in-differences assumptions. For the β_t to represent a valid estimator of the impact of the double minimum wage rule on the share of private sector employees who leave formal employment, we require that the evolution of the share of employees in higher wage bins be a valid counterfactual for workers who report earning at the minimum wage. Pre-trends in this case are more challenging to examine with only two years of data on exits prior to the double minimum wage rule. Nevertheless, the lack of pre-trends in this

[22] An alternative would be to analyze formal employment responses over a two-year time horizon, as we do in much of our analysis of reporting responses. The downside of this approach would be that we additionally miss spells starting between March and December 2005.

[23] Unlike in our estimation strategy for reporting responses discussed in Section 5.2, we do not estimate a constant treatment effect version (the analogue of Equation (14)), because over time the composition of workers reporting to earn the minimum wage and reporting to earn in the wage bins just above changes due to our measured employment response. The Great Recession also appears to have had disparate impacts on workers in different parts of the wage distribution and in different sectors.

time period provides suggestive evidence on the validity of our assumptions. Further, we show that there is no effect among public sector employees who can act as a placebo group for this analysis. Another concern is the potential effect of the double minimum wage rule on the wage bins that we use as controls in this analysis. We do not observe any change in the pre-period or immediately following the introduction of the double minimum wage rule among the control wage bins, but again, our pre-period is short for this analysis. In a robustness analysis, we examine wage bins that are above the double minimum wage (rather than between the minimum wage and the double minimum wage). The advantage of using these higher wage bins is that they are not affected by the double minimum wage rule. The disadvantage is that workers in these wage bins are likely different from workers who honestly report earning the minimum wage.

6 Results

In this section, we use the introduction of the double minimum wage rule at the end of 2006 to provide evidence on the underreporting of earnings at the minimum wage. We start by providing cross-sectional evidence on the distribution of earnings prior to the introduction of the double minimum wage rule (in 2005) and after the introduction of the double minimum wage rule (2007). A spike appears in the distribution at double the minimum wage in 2007 among private-sector employees and the self-employed. We then exploit the panel structure of our data to provide evidence on transitions between different wage levels over time and show that a substantial fraction of workers report to have doubled their earnings after earning just the minimum in 2005. In addition, our findings on transitions by industry, firm size, ownership, and measures of firm quality suggest these responses are larger where prior evasion was more likely. Observable characteristics of workers concentrated at the new threshold show an anomaly at the reporting thresholds; using the distribution of observables characteristics can provide a useful methodology when only cross-sectional data is available. When we analyze the concentration of the reporting effect across firms, we find that workers who reported earning the minimum wage and responded to the double minimum wage rule were likely to be pooled in the same firms with other such workers. The geographic concentration of the reporting response suggests that either local economic factors were important in determining evasion behavior or the double minimum wage rule had different salience in different

areas.

6.1 Main Results

Figure 3 shows the distribution of monthly earnings in 2005 (in blue) and 2007 (in red) separately for private sector employees in Panel (a), the self-employed in Panel (b), and public sector employees in Panel (c). In 2005, all three groups show some excess mass at the amount of the monthly minimum wage, though it is much larger for the private sector than for the public sector and it is especially large for the self-employed. 19.9% of private sector employees, 68.5% of the self-employed, and 1.1% of public sector employees report earnings at the monthly minimum wage in 2005. After the introduction of the double minimum wage rule, in 2007, the amount of excess mass at the minimum wage decreases for private sector employees and the self-employed, though it is still substantial in these sectors. The amount of excess mass remains the same for public sector employees. 5.8% of private sector employees, 30.9% of the self-employed, and 1.1% of public sector employees are reported to earn the minimum wage in March 2007. A new excess mass point appears in the distribution of earnings for private sector employees and the self-employed, but not for public sector employees. In 2007, 5.4% (up from 1.9% in 2005, a 2.8-fold increase) of private sector employees and 16.3% (up from 0.3%, a 54-fold increase) of the self-employed report earning double the minimum wage. The share of public sector employees earning double the minimum wage remains virtually unchanged at 2.51% in 2007 (2.57% in 2005), as we could expect from a group that is least likely to evade taxes by underreporting their earnings.

Making use of the panel structure of our data, Figure 4 shows transitions over time between different wage levels separately for private sector employees in Panels (a) and (b), the self-employed in Panels (c) and (d), and public sector employees in Panels (e) and (f). For each sector, the first panel displays the percentage of employees who transition between 2003 (on the x-axis) and 2005 (on the y-axis) between each of the wage bins, and the second panel displays the percentage of employees who transition between 2005 (on the x-axis) and 2007 (on the y-axis) between each of the wage bins. Consistent with the cross-sectional figures (Figure 3) the first panel for each sector shows some concentration of earnings at the minimum wage and also shows that wages are quite stable across years (39%, 82% and 38% of earnings remain in the same earnings bin relative to the minimum wage among the private sector employees, self-employed and public sector workers,

respectively). The second panel shows that while wage dynamics do not change in the public sector between the 2003–2005 and 2005–2007 periods, the introduction of the double minimum wage rule is associated with a substantial share of workers reporting the minimum wage transitioning to reporting double the minimum wage among private employees. We find that 10.5% of private sector employees reporting the minimum wage in 2005 report at the double minimum wage in 2007. This means that around 2% of all workers in the private sector report at the minimum wage in 2005 and at the double minimum wage in 2007. An even stronger transition response is observed among the self-employed, for whom it might have been the easiest to evade taxes before the new rule but also to report the minimum which they think lowers their chance to be audited. We find that 19.2% of the self-employed reporting at the minimum wage in 2005 report at the double minimum wage in 2007. This means that 10% of all the self-employed report at the minimum wage in 2005 and at the double minimum wage in 2007, suggesting a large fraction of prior minimum wage earners falsely reporting the lowest possible earnings and paying the corresponding taxes.

To estimate changes in reported earnings in a formal regression, Panels (b) and (c) of Figure 5 collect coefficients from event study estimates of the share of workers reporting to earn double the minimum wage, comparing private-sector employees (in Panel (b)) and the self-employed (in Panel (c)) to public-sector employees, based on Equation (13). We show results with no additional controls (in blue) and controlling for gender, age group, and 2003 residence (in red). Panel (b) shows that prior to the introduction of the double minimum wage rule, the difference between the share of workers reporting earning at the double minimum wage in the public and private sectors was stable. (Panel (a) shows that not only was the difference stable, but the level was stable in both sectors.) Among private sector employees, the share of workers reporting earning at the double minimum wage increased by 3.7 percentage points relative to public sector employees in 2007. Panel (c) shows that prior to the introduction of the double minimum wage rule, the difference between the share of workers reporting at the double minimum wage in the public sector and among the self-employed was stable. (Panel (a) shows that not only was the difference stable, but the level was stable in both sectors.) Among the self-employed, the share of workers reporting this amount increased by 16 percentage points relative to public sector employees in 2007.

Table 5 shows our estimates after pooling the years prior to the reform (2003-2006) and after (2007-2010), based on Equation (14). We estimate that relative to public sector employees, the share

of private sector employees reporting double the minimum wage was 2.3% higher and and the share of the self-employed reporting double the minimum wage was 11.4% higher after the introduction of the double minimum wage rule. These pooled estimates are lower than the event study estimates comparing 2006 and 2007 because after 2007, the share of workers reporting earning double the minimum wage falls. We discuss these dynamics in more detail below in Section 6.3.

6.2 Heterogeneous Effects

We examine heterogeneous responses along various characteristics of private-sector employees who remain formally employed in 2007. Panel (a) of Figure 6 shows the share of minimum wage earners in 2005 who transition to the double minimum wage in 2007 by gender, age, and skill level. Men who earned at the minimum in 2005 are 3.5 percentage points (43%) more likely to report earning double the minimum wage than women. The likelihood of transitioning between the minimum wage in 2005 and its double in 2007 is approximately the same by age group. Differences are starkest by skill. 4.6% of workers in an occupation with mostly primary education who reported earning the minimum wage in 2005 report earning its double in 2007, similar to workers in occupations with mostly lower secondary education or less, whose transition probability is 7%. By contrast, the transition probability is much higher among workers in more high-skilled jobs: 15.1% among those with mostly upper secondary education and 24.9% among those with mostly tertiary education prevalent in their occupation. These patterns are consistent with the interpretation that among more highly skilled workers those that reported the minimum wage prior were more likely to be earning at (much) higher levels in effect than their less skilled counterparts. (Appendix Figure A1 shows the evolution of the share of private sector employees who report earning at the double minimum wage by worker characteristics, including gender, age, and skill level, over our entire time period.)

Tax evasion might be less feasible in more prominent businesses. Panel (b) of Figure 6 shows the share of minimum wage earners in 2005 who transition to the double minimum wage in 2007 by ownership, firm size, and industry. It is apparent that the overall 10.5% transition rate of 2005 minimum wage earners to double the minimum wage in 2007 (among those who remain formally employed) masks substantial heterogeneity along all three dimensions. Domestic firms have a 5.0 percentage point (75%) higher transition rate than foreign-owned firms, who are likely to have

different internal systems and culture around truthful reporting. Workers in smaller firms also have much higher transition rates than workers in larger firms: firms of observed size 1–5 have a transition rate of 13.8%, while firms of observed size 6–50 have 8.2%, and those of 51–125 have 3.5%. Among the largest firms, with observed size above 125, only around 3.3% transitioned between the minimum wage and its double during the 2005–2007 period, no higher than in other years, as we show in Appendix Figure A2. Again, larger firms might have been much more conducive to honest reporting all along, if some collusion to evade is harder to coordinate in larger groups (Kleven, Kreiner and Saez, 2016). Construction, Trade, and Transportation have much higher transition rates (13.1%, 11.5%, and 11.8%, respectively) than Agriculture, Mining and Manufacturing, and Accommodation and Food (7.3%, 7.3%, and 6.2%, respectively). All three of these findings on heterogeneity by ownership, firm size, and industry are qualitatively consistent with studies that use other data sources, including surveys, and other methodologies to directly estimate tax evasion in Hungary (Elek, Scharle, Szabó and Szabó, 2009*a*; Elek and Köllő, 2019). (Appendix Figure A2 shows the evolution of the share of private sector employees who report earning at the double minimum wage by firm characteristics, including ownership, firm size, and industry, over our entire time period.)

Lower-quality firms might not be able to afford the full tax bill on their labor, though evaders might look more productive on paper (employing more labor off the books). In addition to standard firm characteristics, we also examine heterogeneity in total factor productivity as a proxy for "firm quality". Panel (c) of Figure 6 shows transitions by TFP quartiles. There is a negative association between TFP and transitions from the minimum wage to the double minimum wage. We interpret this finding to suggest that firms that are more productive are less likely to underreport worker earnings. (Appendix Figure A3 shows the evolution of the share of private sector employees who report earning at the double minimum wage by total factor productivity over our entire time period.)

6.3 Additional Evidence

Observables at the Double Minimum Wage. So far, we have used the panel structure of our data to observe individual workers moving from the minimum wage to the new double minimum wage audit threshold to argue that these patterns are consistent with previous underreporting at the minimum wage. This method can deliver relatively precise individual-level and firm-level estimates

of underreporting. An alternative approach makes use of the richness of the administrative data available and the distribution of various worker characteristics throughout the earnings distribution. The advantage of this approach is that it only requires a single year of data, with the obvious disadvantage that it can only help us document the extent of likely underreporting but not its individual (or corporate) source. This approach is in some sense similar in flavor to the "unused observables" approach of Finkelstein and Poterba (2014). There the authors show that residential location is correlated in the U.K. with both the demand for annuities and mortality, but remains unused for the purpose of pricing annuities, demonstrating the presence of asymmetric information. In our context, we show that a variety of variables that are not used by tax authorities for audits and even variables that would not appear to be related to taxation at all have excess mass in their distributions at the double minimum wage threshold after the reform. Figure 7 demonstrates this phenomenon for four covariates: gender, skill level, residing in the capital (in 2003), and utilizing any outpatient care in a year. All four variables have smooth distributions around the double minimum wage threshold among public sector employees both before and after the introduction of the double minimum wage rule and among private sector employees before the introduction of the double minimum wage rule. However, after the introduction of the double minimum wage rule, all four variables shows spikes among private sector employees at the double minimum wage threshold.[24]

Geographic Concentration. We also find the transition rates from the minimum wage to the double minimum wage between 2005 and 2007 by districts of Hungary closely move together for private sector employees and the self-employed. Figure 8 shows this rate to vary between 1% and 22% among private sector employees, with a wider dispersion (3-28%) for the self-employed. We see a strong positive association in the district-specific transition rates between the two sectors (the slope of the regression line 0.92). This suggests strong spatial clustering of tax evasion or in the perception of the double minimum wage rule. The self-employed face different institutions for wage bargaining and somewhat different incentives to avoid or evade labor taxes, but their behavior is a good measure of local salience of the rules and prevalance of prior evasion (Chetty, Friedman and Saez, 2013). It is reassuring to see that in areas where only a small share of the self-employed reacted to the double minimum wage rule, transition rates were similarly low among private sector

[24] Choudhary and Gupta (2019) analyze other outcomes in the context of a more conventional bunching response.

employees; this suggests that there are no confounding reasons for reporting at the double minimum wage in 2007.

Cross-Firm Concentration. An important conceptual question for understanding tax evasion around the minimum wage is whether this is primarily a firm-side or worker-side phenomenon. With third-party reporting, the worker cannot underreport on their own (Kleven et al., 2011), but they could have a deciding say in an agreement with their employer about their reported earnings. While the reform is too short-lived to track workers moving between employers with different response rates, it is still instructive to look into correlated behavior without breaking the reflection problem (Manski, 1993). We relate responses to the double minimum wage rule measured at the level of individual workers to responses measured for other employees of the same private-sector employer. Figure 9 shows response rates of workers by the average response rate of their peers in the company. Panel (a) suggests that at lower levels of firm response, when less than half of coworkers moves from the minimum wage in 2005 to double the minimum wage in 2007 (among those who remain employed there), there is an overall positive association between individual and peer behavior. At higher levels of firm response, when more than half of others respond, individual responses are less closely associated to peers', 70-80% of workers respond on average. Panel (b) shows something similar for exits (foreshadowing Section 6.4), where we bin firms by differential relative exit rates of 2005 minimum wage workers compared to those earnings slightly more. Workers reporting to earn the minimum in 2005 are often less likely to leave than coworkers who are paid more, and for this group we see a tightly estimated 18% propensity to leave irrespective of peers' relative propensity (the slope being zero has a p-value of .19). At firms where others on the minimum wage are more likely to leave than higher earners, we do see the individual exit rates moving with peers' (with a slope of .69), which suggests the exits are concentrated only when firms let go disproportionately many minimum wage workers, consistent with this phenomenon being less of an organic feature of the labor market and more about collusion, the salience of the policy, and the extent of prior evasion.

These patterns are consistent with our understanding of market power of employers in wage setting. However, the concentrated responses might also bolster the story that these are responses to the tax rules by employers who previously underreported earnings, similarly to how the geographic

correlation between the responses of private sector employees and the self-employed suggests a role for the salience of the reform. Exits being concentrated only if disproportionately likely among minimum wage workers is similarly consistent with these workers underreporting earnings originally and either being priced out by the higher tax burden or continue working but completely undocumented, as we discuss in Section 6.4.

Dynamics of Concentration at the Threshold. Our analyses above rely on the 2007 introduction of the double minimum wage threshold and document reported earnings responses relative to 2005. However, we observe earnings for the 2003–2011 period, which allows us to show the dynamics of concentration at the double minimum wage threshold over time. Panel (a) of Figure 5 shows the evolution of the share of workers by sector who earn at the double minimum wage threshold. Prior to the 2007 introduction of the double minimum wage threshold, the share of workers at this wage level was stable among private employees (at 2.1 %), the self-employed (at 0.3 %) and among public employees (at 2.8 %). In 2007, the share of workers at the threshold increased sharply among private employees (to 5.4 %) and the self-employed (to 16.3 %), but remained stable for public employees. In the subsequent years, the concentration of workers at the threshold decreased gradually among both private sector employees (4.3 % in 2008, 3.4 % in 2009, and 2.8 % in 2010) and the self-employed (14.0 % in 2008, 9.8 % in 2009, and 5.5 % in 2010). Recall that after 2010, the double minimum wage audit threshold is no longer in effect. Our panel only runs to 2011 and then the share of workers at the double minimum wage is the same as prior to the 2007 introduction of the double minimum wage rule. We view the post-2007 gradual decrease in the share of workers at the audit threshold as evidence of dissipating perceptions of the audit threat.

By 2010, around 50% of those that initially moved from the minimum wage to its double move to wages that are lower than twice the minimum wage, both among private sector employees and the self-employed. By 2011, the same ratios are around 70%. The complete dissipation of the excess mass of workers at the double minimum wage threshold after the threshold was no longer in effect is consistent with the concentration at the threshold being a consequence of a response to the audit threat and with earlier underreporting.

Appendix Figures A1, A2, and A3 show the evolution of the share of private sector employees who report the double minimum wage threshold by worker characteristics, firm characteristics,

and measures of firm quality, respectively. They are analogous to those in Figure 6 extending the results to our entire time period. They show that in each subgroup, the share of workers earning at double the minimum wage is stable prior to 2006, jumps by a large amount in 2007 and then decreases gradually over time. In 2011, when the reform is no longer in effect, the share of workers reporting double the minimum wage is roughly the same in each subgroup as their pre-reform level. Appendix Figure A1 confirms that the reporting response is much large for men, is similar by age group, and is decreasing in skill level. Appendix Figure A2 confirms that the reporting response is concentrated in domestic and small firms and certain industries (construction and trade show the largest response). Appendix Figure A3 confirms that the reporting response is larger for firms low total factor productivity.

Additional Robustness. As described in Section 5, we use absolute wage bins of size 5,000 HUF (≈$17) for our main results on reporting at the level of the double minimum wage. An alternative wage bin definition would fix the relative distance from the double minimum wage in each year. In Appendix Figure A4 and Appendix Table A1, we re-estimate our main results from Figure 5 and Table 5 defining a band between 95% and 105% of the annual level of the double minimum wage. We find that our results are virtually unchanged under this alternative definition.

6.4 Impact on Formal Employment

In addition to the increase in reported wages among some workers previously reporting to earn the minimum wage that we documented in Section 6.1, in this section we examine whether the introduction of the double minimum wage rule impacted apparent exits from formal employment. The underlying idea is that the perceived increase in audit probabilities below the new threshold made some workers who previously had higher off-the-books earnings report higher formal earnings, but for others this increase in the cost of formal employment may have been an incentive to report no formal earnings at all. We first show that there was an increase in the probability of leaving formal employment among workers that were most likely impacted by the reform. Relative to workers at wage bins above the minimum wage, workers at the minimum wage are more likely to leave formal employment when the double minimum wage rule is introduced. We then turn to examining which worker and firm characteristics are associated with an increased probability of

leaving formal employment.

Figure 10 shows the probability of leaving formal employment in each year among those who earned the minimum wage and in three relative wage bins above the minimum the year before by sector. The raw trends in Panels (a) and (c) show clear patterns only for the private sector employees. Prior to the introduction of the double minimum wage rule, the probability of leaving formal employment was relatively stable for each wage level among the private sector employees. When the double minimum wage rule is introduced in September 2006, the probability of leaving formal employment remains stable only among those earning the minimum wage, it decreases for the higher earners. Our event study regression estimates (Panels (b) and (d)) show that these results remain unchanged when we compare minimum wage earners to any of the relative wage bins above them and also when we include controls for gender, age group, and initial residence. We do not find evidence for an impact on formal employment among the public sector employees. Among the private sector employees, the probability of leaving formal employment increases by around 2% when the double minimum wage rule is introduced. The estimated coefficients for year 2007 are also reported in Table 6. This differential increase in the probability of leaving formal employment for only the sector and only the wage level that we showed in Section 6.1 to be prone to underreporting is consistent with some firms opting to go informal in the face of higher costs of formality while others opting to become more formal given the audit threat. In Section 7 we formalize this intuition.

Figure 10 reports exit results also for years 2008-2011, however, since the composition of minimum wage earners change after the introduction of the double minimum wage rule, we focus on the estimated effects for 2007, only.

Figures 11, 12 and 13 show the the evolution of the exit probability over time by gender, age, skill level, ownership, size, industry and total factor productivity, comparing those reporting earning the minimum wage to those in relative wage bin 3. We see little evidence for heterogeneities in exit responses. The strongest finding is that exit response is more pronounced among the low-skilled.

Figure 14 shows what happens to private sector employees who initially exit formal employment when the double minimum wage rule is introduced. The figure tracks the employment status and government program participation of those who reported earning the minimum wage (Panel (a)) or earning in relative wage bin 2 (Panel (b)) in December 2005 but did not work in January 2007. Overall, we find that approximately 60% of exits from formal employment are short-term (last for

at most a year), while about 40% are long-term (last for at least 4 years). We find that employment and unemployment insurance rates are similar among the two wage groups: within one year, 38% vs. 36% of them return to formal employment and this number increases gradually, reaching 45% vs. 41% by 2011. Initially, 35% are observed to be unemployed in both wage groups, this drops to 15% vs. 16% within one year, and then gradually decreases to 12% in both wage groups. Participation in other government transfer programs, including disability insurance, pension, family leave payment, and other transfer program receipt, is much less likely among those exit formal employment after reporting earning the minimum wage: throughout the period, those who exit formal employment after reporting earning in relative wage bin 2 is 8 percentage point more likely to receive a government benefit than those who exit after reporting earning the minimum wage. On the other hand, those who exit after reporting earning the minimum wage are 8 percentage points more likely to be out of the labor force and not receiving any government transfers. These findings are consistent with workers exiting after reporting earning the minimum wage moving into the informal sector at relatively high rates.

Robustness. Our analysis of the impact of the double minimum wage rule on formal employment relies on a comparison on the employment dynamics of minimum wage earners with the employment dynamics of workers earning in the wage bins just above. This has the advantage that we are comparing minimum wage earners to workers who should be very similar to them if reported earnings are not manipulated. However, it has the disadvantage that workers in these wage bins may react to the double minimum wage rule if they had previously also manipulated their reported earnings, but did so not exactly at the level of the minimum wage. In Appendix Figure A5 (analogous to Figure 10) and Appendix Table A2 (analogous to Table 6), we show results using the three wage bins just above the double minimum wage as reference groups. These wage bins are further from the minimum wage and are potentially less comparable, but are above the double minimum wage and are thus not subject to the reporting incentives created by the double minimum wage. We find that our results are qualitatively similar, but quantitatively smaller than in our original specification.

6.5 Fiscal Effects

We provide a back-of-the-envelope calculation of how minimum wage filers' responses to presumptive taxation impacted the public budget.

Private Sector Employees. In 2005, there were 383,834 minimum wage earners in the private sector (based on data from March). Approximately 7.8% (29,804) of them earned twice the minimum wage in 2007. Had they stayed at the minimum wage, they would have earned around 2,011 million HUF in March 2007. Since in fact, they shifted up to the double minimum wage, they earned 3,981 million. The additional 1,970 million HUF of declared income meant roughly 1,320 million HUF additional tax and social security income for the government, including employer-paid taxes on the gross minimum wage. This makes up approximately 0.4% of government revenue from personal income tax (around 109 billion HUF per month) and social security contributions (around 240 billion HUF per month).

On the other hand, due to the double minimum wage rule, around 2% (7,677) of the minimum wage filers left formal employment over a 13-month horizon. Due to their exits, the net government revenue from the double minimum wage rule among private-sector employees shrinks to around 0.3% of the personal income tax and social security contributions.

Moreover, 1.5% (i.e. roughly two-third of those who left formal employment) of prior minimum wage filers claimed unemployment benefits. This imposed an additional, albeit transitory, negative fiscal externality, implying an overall negative budgetary effect of the new rule among private sector employees.

Self-Employed Workers. Comprehensive fiscal effects need to take account of the self-employed as well. 153,944 of them declared the minimum wage in March 2005, with 15.5% (23,830) moving to double the minimum wage by March 2007. As a result of presumptive taxation, an additional 1,592 million HUF of income was declared, which meant roughly 581 million HUF additional personal income tax and social security income for the government. This makes up approximately 0.17% of the revenue of the public sector from personal income tax and social security contributions.

We do not have evidence for an effect of the double minimum wage rule on the probability of self-employed minimum wage earners leaving the formal labor market. As a consequence, the overall

public net revenue from the double minimum wage rule among the self-employed is around 0.17% of the total revenue from personal income tax and social security contributions. Note some limitations of our calculations here. We focused only on minimum wage filers and did not consider the rule's impact on other low earners. We neglected all other types of taxes paid by the self-employed. We also assumed that the self-employed pay taxes and social contributions the same way as private-sector employees, neglecting the corporate tax deductions from their labor costs. Nevertheless, these results suggest that the first-order effect of the double minimum wage rule was small on the public budget.

7 Welfare Under Evasion

We now present a more formal argument why underreporting at the minimum wage (with no presumptive taxation) would justify higher taxation of those earnings than otherwise would be optimal.

In our framework from Section 3 the only efficiency loss comes from some jobs being priced out as well as the evasion cost g wasting resources. However, the social planner could weigh the surplus generated by different jobs differently, according to whom it accrues to. The weights will be the product of the density of those types overweighted or undercounted according to the social value of the capitalist entrepreneur (α), the worker (β), and the value of public funds (γ).[25] These weights can measure monetary losses and gains as the generalized social marginal welfare weights of Saez and Stantcheva (2016), though they are also reduced-form representations of income valued differently because of different disutility of work (not modeled directly) or because different jobs pay individuals with different material or moral standing. As our empirical work does not recover the true income of evaders, we do not base welfare on this latent primitive either.

We can thus add up profits, wage costs, taxes and penalties as the monetary value of welfare:

$$W = \int_{\theta\in\Theta_3} \alpha(\theta)V(\theta) + \beta(\theta)M + \gamma(\theta)\tau M \,\mathrm{d}\theta + \int_{\theta\in\Theta_2} \alpha(\theta)V(\theta) + \beta(\theta)w(\theta) + \gamma(\theta)(\tau M + \rho p\tau e(\theta)) \,\mathrm{d}\theta + \int_{\theta\in\Theta_1} \alpha(\theta)V(\theta) + \beta(\theta)w(\theta) + \gamma(\theta)(\tau(w(\theta) - e(\theta)) + \rho p\tau e(\theta)) \,\mathrm{d}\theta.$$

[25] Note that for the self-employed, the first two of these should arguably be the same.

The marginal value of a minimum wage hike simplifies to a sum of three terms:

Proposition 2. *The marginal social value of a higher minimum wage is the total of three countervailing factors: (a) the lost profits but higher gross wages from minimum wage reporting firms, (b) the higher gross wage from lower evasion from bunching evaders, and (c) the lost surplus destroyed at the marginal entrant.*

$$\frac{\mathrm{d}W}{\mathrm{d}M} = \int_{\theta_4}^{\theta_{21}} \left(-\alpha(\theta)\lambda(\theta) + \beta(\theta) + \gamma(\theta)\tau\right) \mathrm{d}\theta + \int_{\theta_{32}}^{\theta_{21}} \left(\beta(\theta) + \gamma(\theta)\rho p\tau\right) \frac{\mathrm{d}e(\theta)}{\mathrm{d}M}\, \mathrm{d}\theta - \frac{\mathrm{d}\theta_4}{\mathrm{d}M} \left(\beta(\theta_4)M + \gamma(\theta_4)\tau M\right). \quad (16)$$

Proof. In Appendix Section A.2. □

Not suprisingly, the marginal value of a higher minimum wage can be positive or negative, depending upon a constellation of factors. However, one could derive the social optimum where this is zero. In any case, the trade-off between enforcement and higher minimum wage is apparent from the cross-derivative of welfare with respect to the two policy instruments, M and p.

It can be a reasonable assumption that any recipient is unsated and worthy (which would be violated by a social desire to hurt cheaters, for instance):

Assumption 4. *All reduced-form welfare weights are non-negative, $\alpha(\theta) > 0$, $\beta(\theta) > 0$, $\gamma(\theta) > 0$, $\forall\theta$.*

This is sufficient to prove that weaker enforcement raises the value of minimum wage increases.

Theorem 1. $\frac{\mathrm{d}^2W}{\mathrm{d}M\,\mathrm{d}p} < 0$*, thus the marginal social value of raising the minimum wage rises when audit probabilities fall. Higher minimum wages are socially optimal in an environment with looser enforcement.*

Proof. In Appendix Section A.3. □

Enforcement and presumptive taxation can thus be substitutes. If presumptive taxation is tied to the minimum wage, as if often the case in practice, higher minimum wages in environments with poor enforcement can follow.

8 Conclusion

This paper demonstrates that even in a high-income country, wage misreporting, specifically at the minimum wage, can be an empirically relevant concern for tax policy. We showed that a large fraction of private-sector employees and the majority of the self-employed report earnings at the minimum wage without presumptive taxation or targeted audits in Hungary. After a policy experiment that threatened firms with audits if they declared earnings below twice the minimum wage, we document significant shifts in the earnings distribution consistent with previous underreporting. We show that 10.2% of private-sector employees and 19.2% of the self-employed who previously reported earning the minimum immediately declare earnings that are twice as high. There is no such response among public sector employees. The response is concentrated in industries prone to tax evasion and in small and domestic firms that other studies found to have the highest rates of tax evasion. It is also concentrated among firms that are of lower quality. The correlation of suspicious declarations between coworkers, as well as between private-sector employees and the self-employed nearby, further strengthen our case that some minimum wage earnings had been misreported before.

We also demonstrate that the reform led to an increase in exits from formal employment, which highlights the implicit trade-off in raising the threshold of presumptive taxation (which is just the minimum wage in most cases) for potential evaders. The concurrent increase in reported earnings and exits among similar firms is consistent with the notion that some workers and firms chose full informality rather than semi-formal arrangements. On the one hand, tax policy can increase reported earnings, in some sense making some employment more formal and extracting more taxes from it. On the other hand, an unintended consequence of such policies may be the loss of formal employment, decreasing tax revenue.

We believe that our findings are pertinent for tax and minimum wage policy and the taxation of potentially informal work in particular. Policymakers should be cognizant of misreporting and the corresponding potential to boost tax revenues at the cost of some informality in response to a minimum wage hike accompanied by a tax increase. Alternatively, if they already are, this could help explain why some countries have high gross minimum wages that are taxed heavily.

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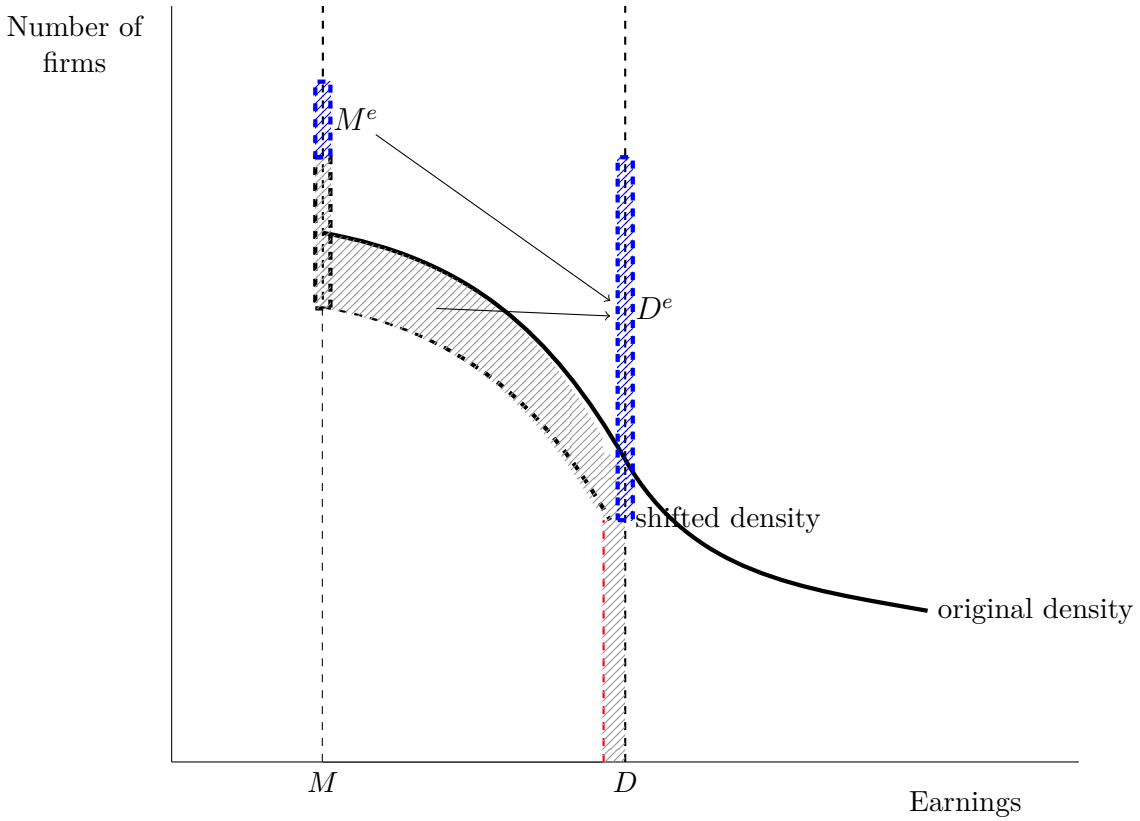
Figure 1: Conceptual Framework With Underreporting: Impact of Stricter Enforcement



Note: Figure shows the impact of stricter enforcement for reported earnings in [M,D]. The black plus blue (M^e) spike at M show the original bunching at M. M^e is the additional excess mass at M caused by some firms underreporting their earnings, partly shifting up to D after stricter enforcement. The shaded area between the original and shifted density lines and the mass of earners to the left of D also indicate a mass of evaders, part of whom bunch at D after stricter enforecement. The blue area of D^e is the excess bunching at D.

Figure 2: Productivity categories

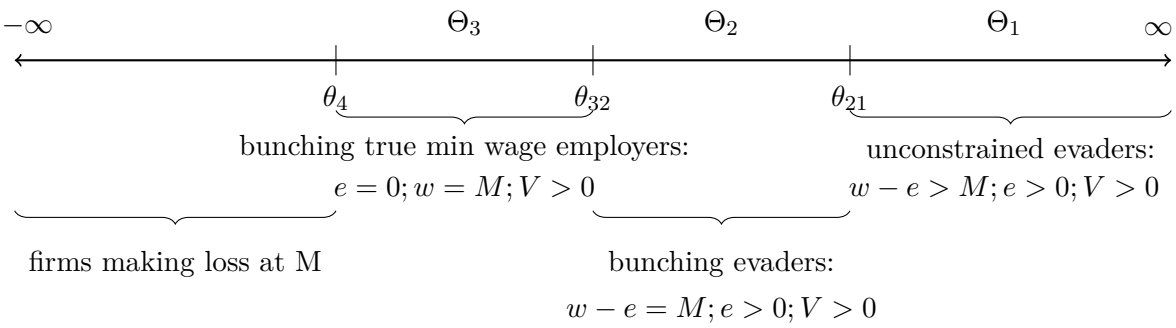
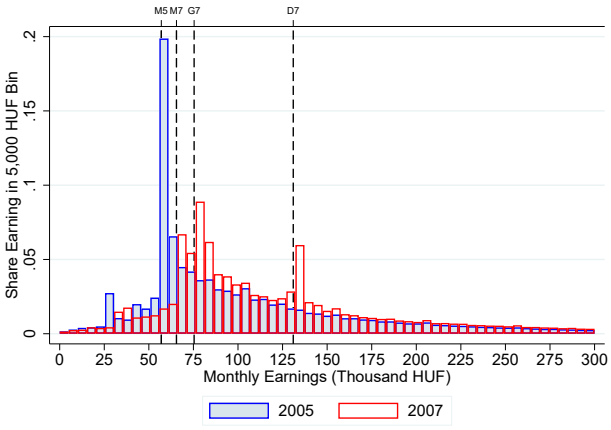
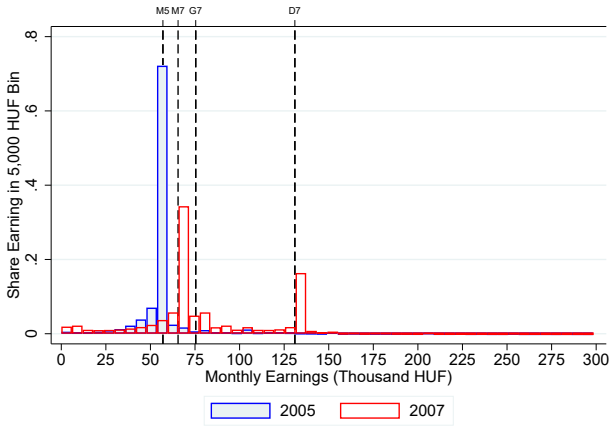


Figure 3: Distribution of Earnings by Sector in 2005 and 2007

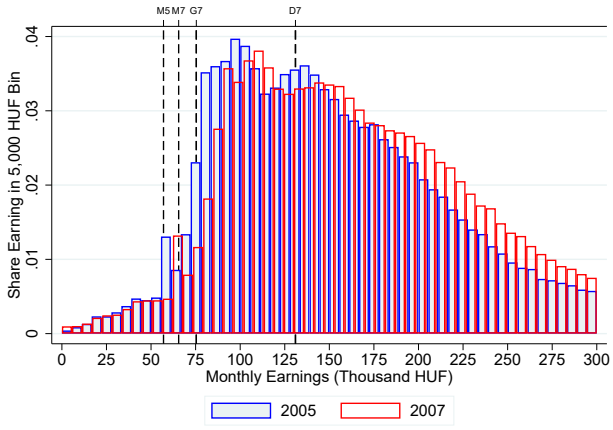
(a) Private Sector Employees



(b) Self-Employed



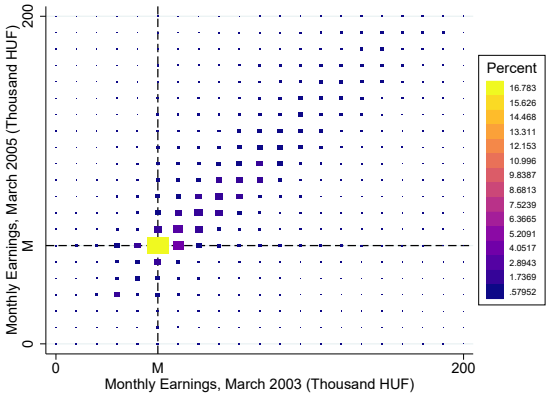
(c) Public Sector Employees



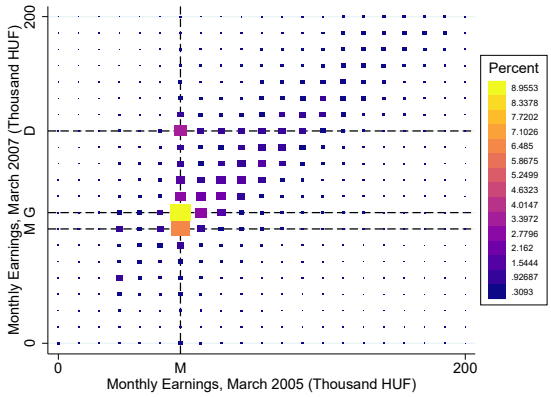
Note: Figure shows the distribution of earnings in March 2005 and March 2007 by sector in 5,000 HUF (≈$17) bins. Panel (a) shows private sector employees, Panel (b) shows the self-employed, and Panel (c) shows public sector employees. The vertical lines show the 2005 and 2007 levels of the minimum wage (M5 and M7, respectively), the 2007 level of the guaranteed wage minimum (G7), and the 2007 level of the double minimum wage (D7). For more details, see Section 5.

Figure 4: Two-Year Earnings Dynamics by Sector

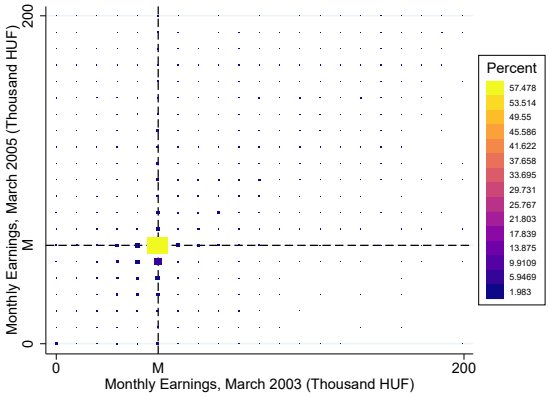
(a) Private Sector Employees, 2003 to 2005



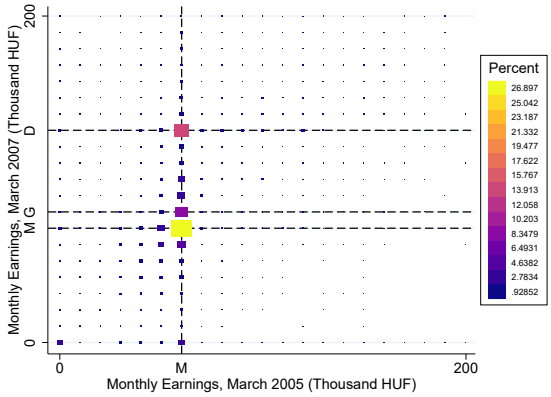
(b) Private Sector Employees, 2005 to 2007



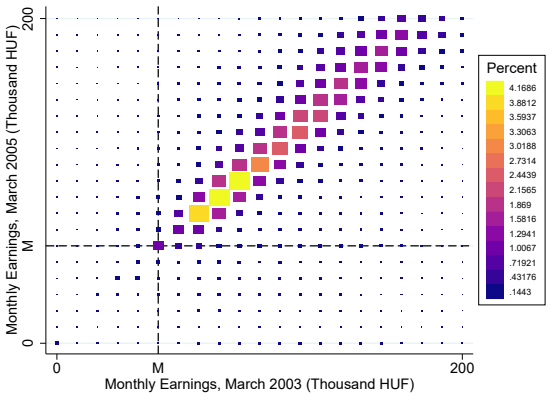
(c) Self-Employed, 2003 to 2005



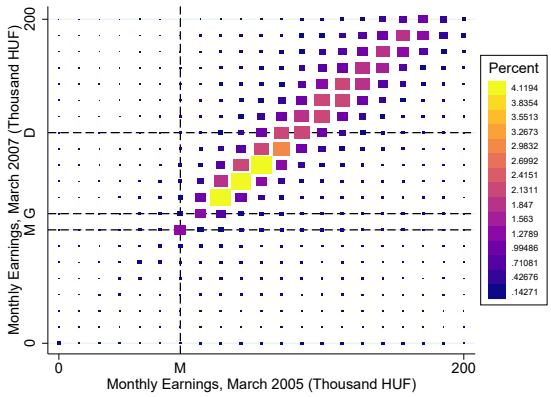
(d) Self-Employed, 2005 to 2007



(e) Public Sector Employees, 2003 to 2005



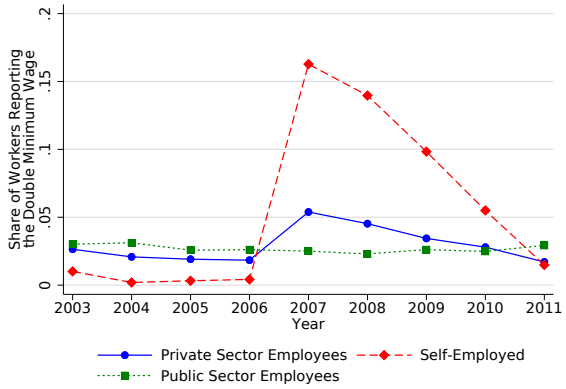
(f) Public Sector Employees, 2005 to 2007



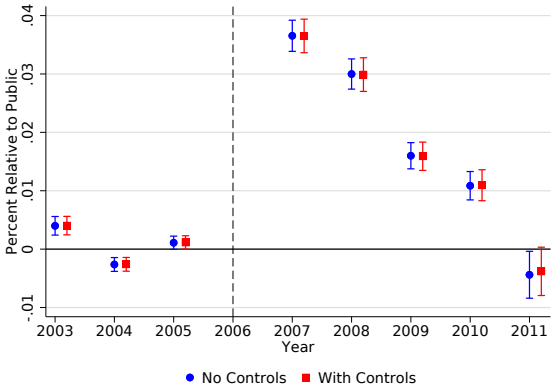
Note: Figure shows two-year transition probabilities of earnings between March 2003 and March 2005 and between March 2005 and March 2007 by sector. For each pair (w_1, w_2) of year t and year $t+2$ earnings, we show what percentage of all workers in the sector who earned w_1 in year t and w_2 in year $t+2$. Panels (a) and (b) show private sector employees, Panels (c) and (d) show the self-employed, and Panels (e) and (f) show public sector employees. Panels (a), (c), and (e) show transition rates between years 2003 and 2005 and Panels (b), (d), and (f) show transition rates between years 2005 and 2007. The horizontal and vertical lines stand for the year-specific level of the minimum wage (M), the year-specific level of the guaranteed minimum wage (G), and the year-specific level of the double minimum wage (D). For more details, see Section 5.

Figure 5: Share of Workers Reporting Earnings at the Double Minimum Wage Over Time

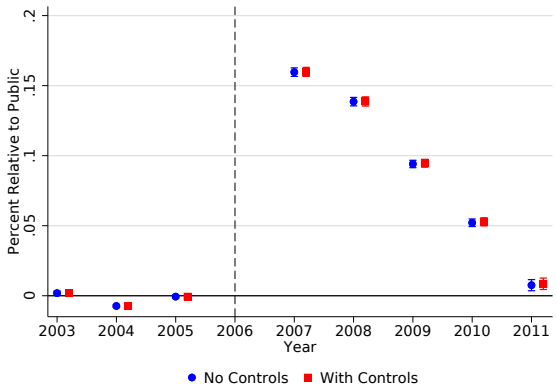
(a) Raw Trends



(b) Regression Estimates: Private Sector Employees



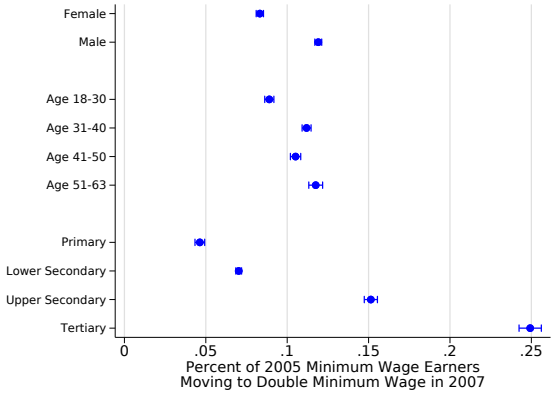
(c) Regression Estimates: Self-Employed



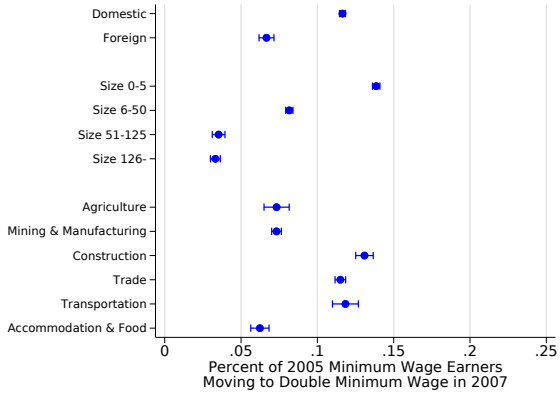
Note: Figure shows the share of workers who report earning double the minimum wage over time by sector. Panel (a) shows shares separately for private sector employees, the self-employed, and public sector employees. Panel (b) shows event study regression estimates comparing private sector employees to public sector employees, based on Equation (13). Panel (c) shows shows event study regression estimates comparing the self-employed to public sector employees, based on Equation (13). In Panels (b) and (c) the blue dots show estimates with no additional controls and the red dots show estimates controlling for gender, age group, and location (capital vs not). Standard errors are clustered at the firm level, 95% confidence intervals are displayed. For more details, see Section 5.

Figure 6: Heterogeneity in Reporting Response

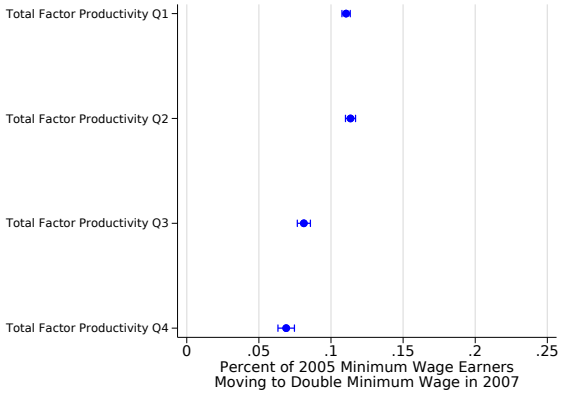
(a) By Worker Characteristics



(b) By Firm Characteristics

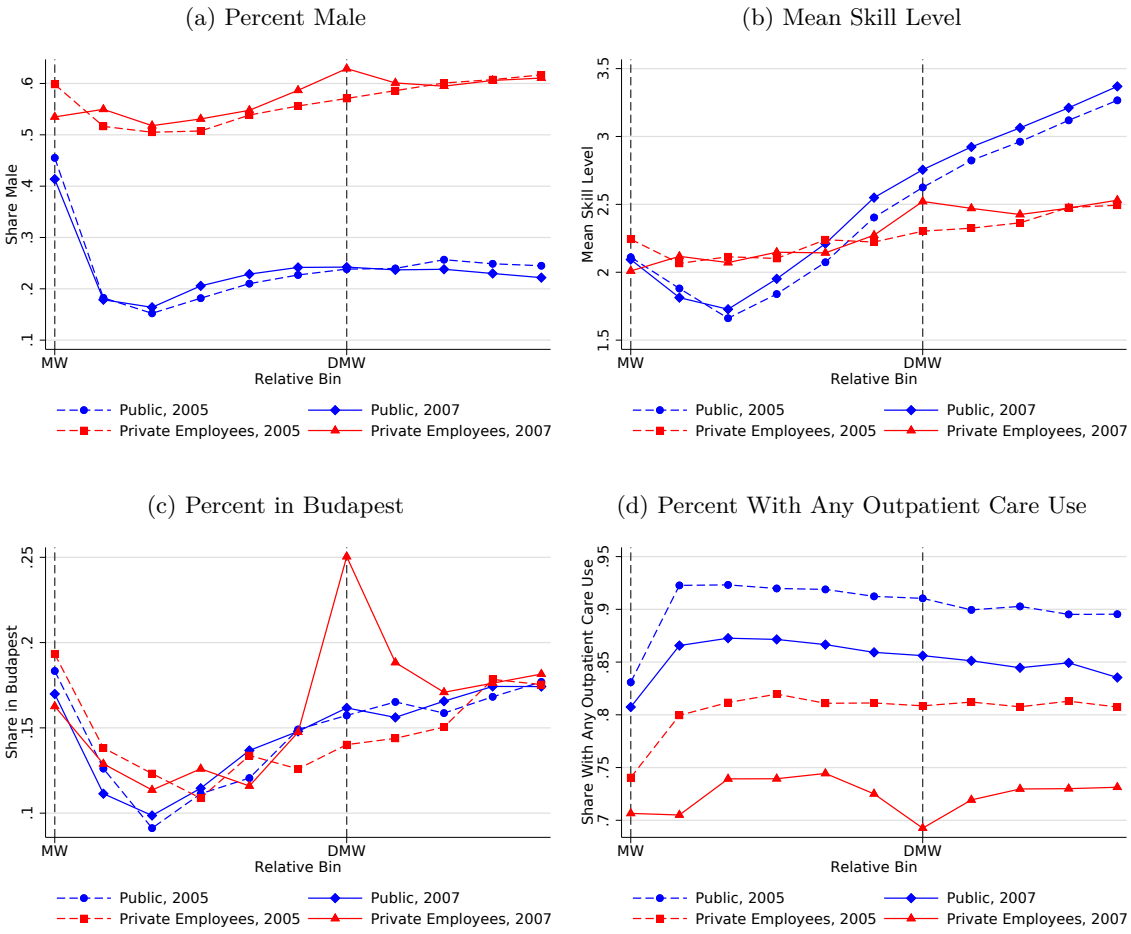


(c) By Firm Quality



Note: Figure shows the share of private sector employees who report earnings at the minimum wage in March 2005 and report earnings at the double minimum wage in March 2007 by worker characteristics, firm characteristics, and measures of firm quality. Panel (a) shows estimates by worker characteristics, including gender, age, and skill level. Panel (b) shows estimates by firm characteristics, including ownership, observed size, and industry. Panel (c) shows estimates by total factor productivity. The error bars show 95% confidence intervals. For more details, see Section 5.

Figure 7: Distribution of Observable Characteristics Over the Wage Distribution



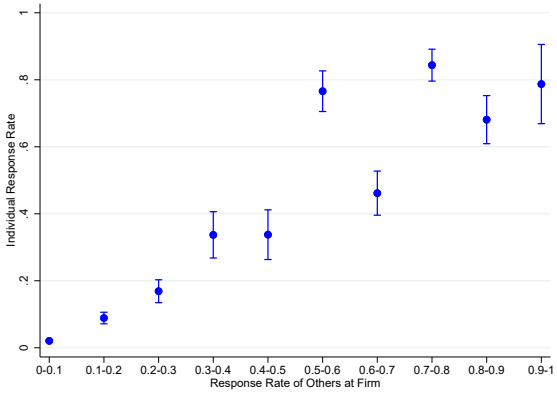
Note: Figure shows the distribution of four observable variables over the wage distribution for public sector employees (blue lines) and private sector employees (red lines) in 2005 (dashed lines) and in 2007 (solid lines). For each relative wage bin, Panel (a) shows the percent of workers who are male, Panel (b) shows the mean skill level (measured on a 1-to-4 scale, with 1 corresponding to primary education and 4 corresponding to tertiary education prevalent in one's occupation), Panel (c) shows the percent of workers in Budapest, and Panel (d) shows the percent of workers with any outpatient care use. M stands for the year-specific level of the minimum wage and D stands for the year-specific level of the double minimum wage. For more details, see Section 5.

Figure 8: Reporting Response by Districts and Sector

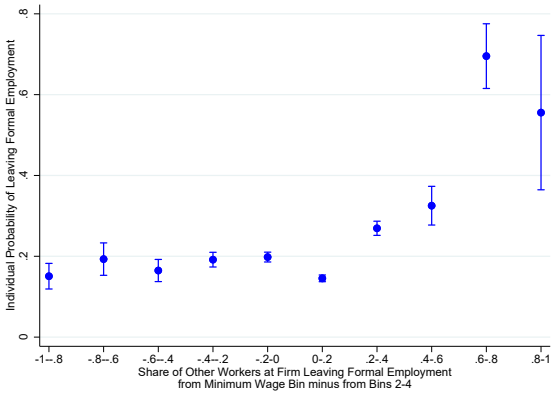
Note: Figure shows the share of private sector employees (x-axis) and self-employed (y-axis) who report earnings at the minimum wage in March 2005 and report earnings at the double minimum wage in March 2007 by districts. The size of the circles reflect the relative population size of a district. The red line is the linear fitted line (slope = 0.92).

Figure 9: Response of Workers and Other Workers at the Same Firm

(a) Share of Minimum 2005 Minimum Wage Earners Moving to Double Minimum Wage in 2007



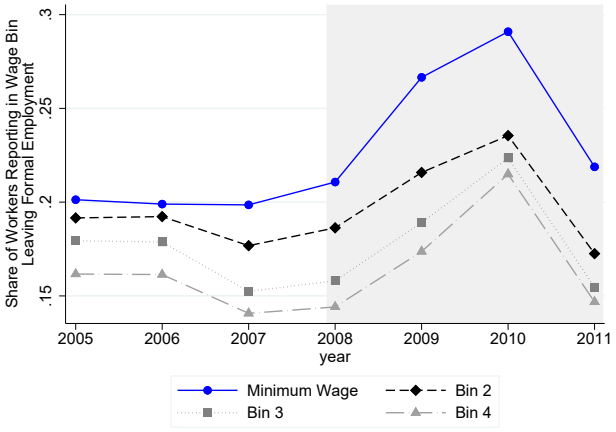
(b) Share of Minimum 2005 Minimum Wage Earners Leaving Formal Employment in 2007



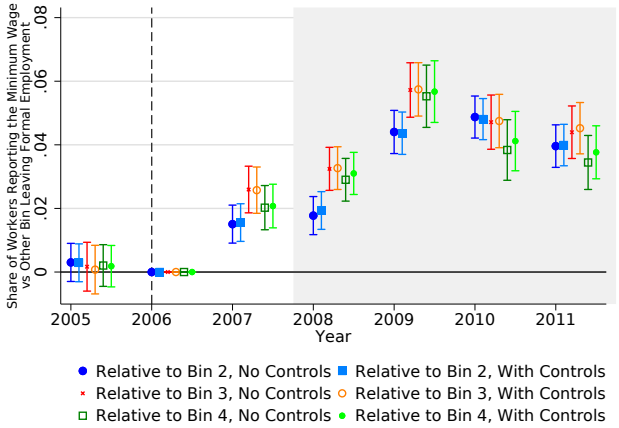
Note: Figure relates individual workers' response to the response of other workers in the same firm. Panel (a) shows the share of private sector employees who report earnings at the minimum wage in March 2005 and report earnings at the double minimum wage in March 2007 by the share of other employees in the same firm who report earnings at the minimum wage in March 2005 and report earnings at the double minimum wage in March 2007. Panel (b) shows the share of private sector employees who report earnings at the minimum wage in March 2005 and leave formal employment by March 2007 by the difference between the share of other employees in the same firm who report earning the minimum wage in March 2005 and leave formal employment by March 2007 and the share of other employees in the same firm who report earning in one of the relative wage bins above the minimum wage and leave formal employment by March 2007. Figure is limited to firms with at least 10 workers reporting earning the minimum wage. For more details, see Section 6.3.

Figure 10: Share of Workers Who Leave Formal Employment by Sector, Wage Bin, and Year

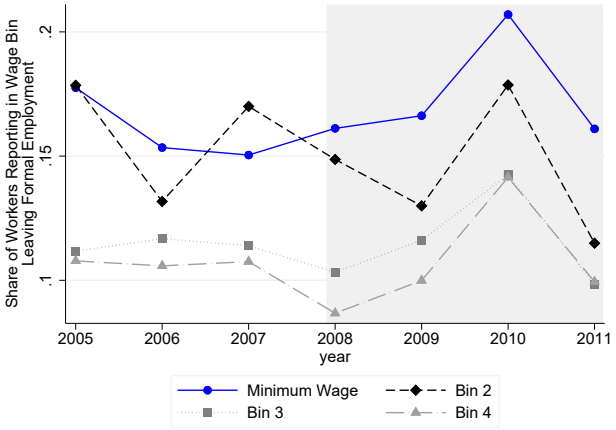
(a) Raw Trends: Private Sector Employees



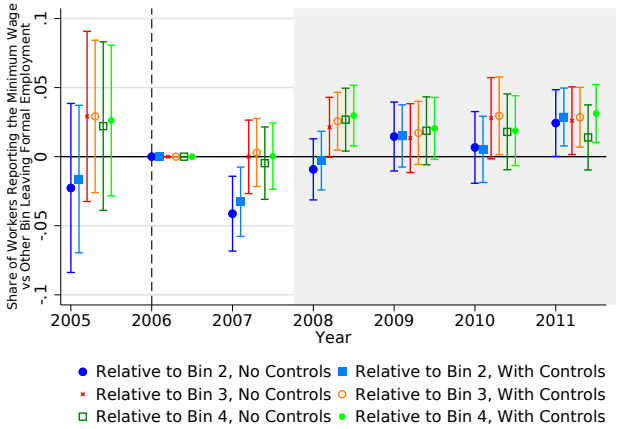
(b) Regression Estimates: Private Sector Employees



(c) Raw Trends: Public Sector Employees

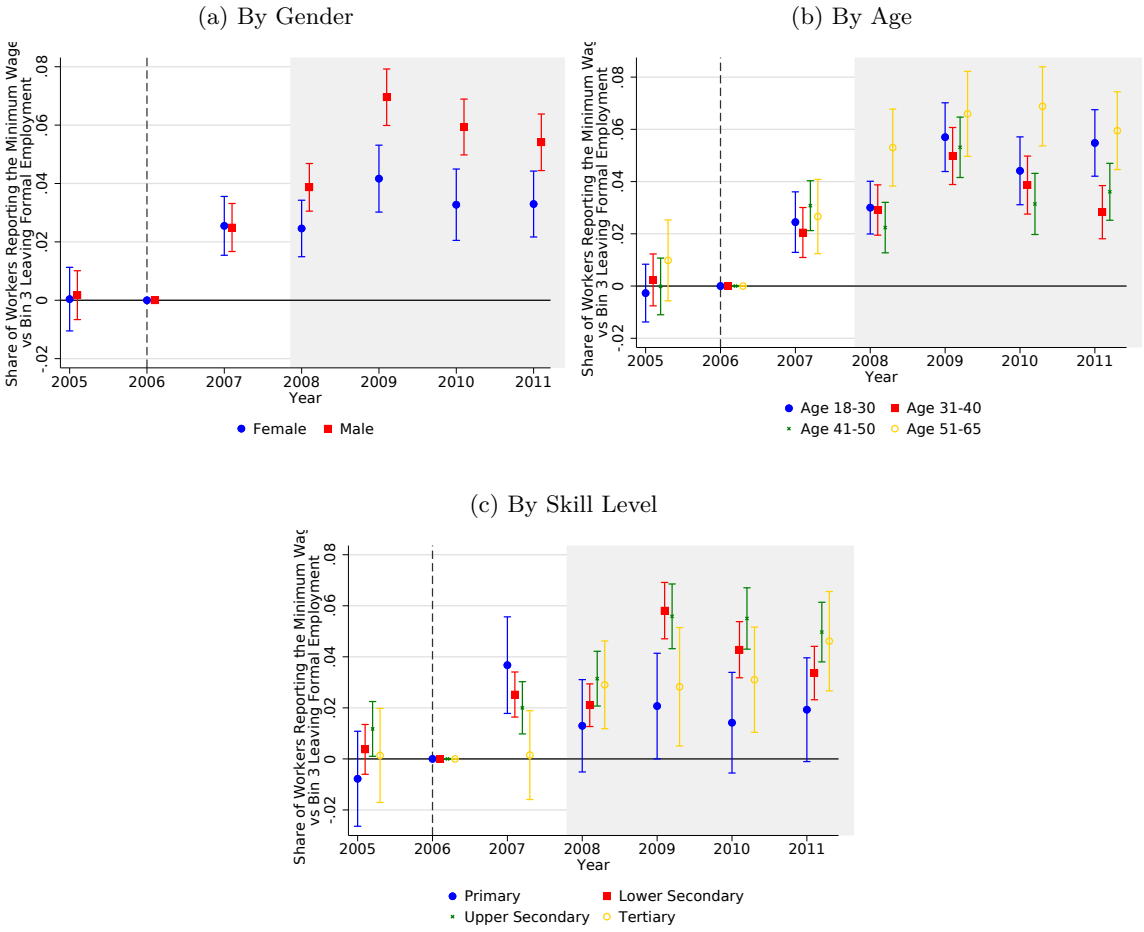


(d) Regression Estimates: Public Sector Employees



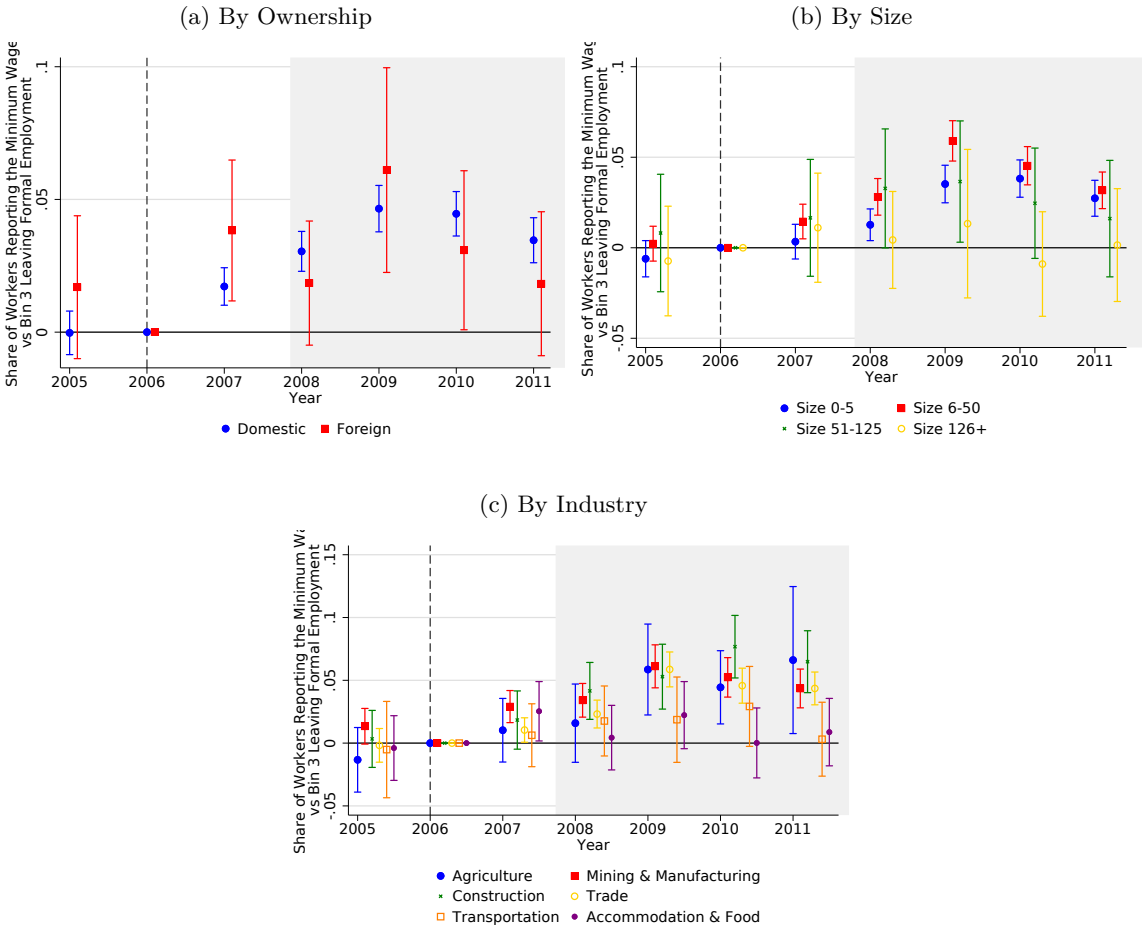
Note: Figure shows the share of workers who leave formal employment by January, by sector and wage bin (in December of two years prior) over time. Panels (a) and (b) show private sector employees, Panels (c) and (d) show public sector employees. Panels (a) and (c) show raw trends for those who report earning the minimum wage in the previous year (in blue), and for those who report in relative wage bins 2, 3, and 4 (in grey). Panels (b) and (d) show event study regression estimates comparing those who report earning the minimum wage to those who report earning in relative wage bin 2 (in blue), those who report earning in relative wage bin 3 (in red), and those who report earning in relative wage bin 4 (in green), based on Equation (15). For each comparison, the first estimate (in a darker color) shows estimates with no additional controls and the second dot (in a lighter color) shows estimates controlling for gender, age group, and location (capital vs not). Standard errors are clustered at the firm level, 95% confidence intervals are displayed. For more details, see Section 5.

Figure 11: Heterogeneity by Worker Characteristics in Probability of Leaving Formal Employment Over Time



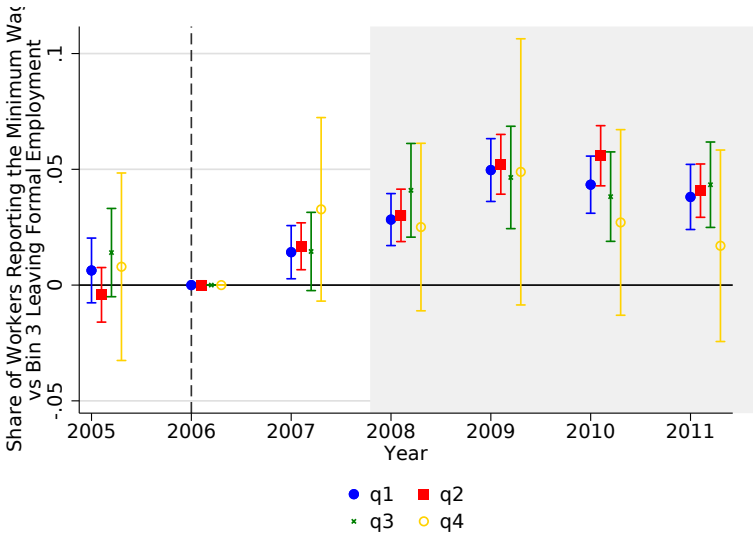
Note: Figure shows the share of private sector employees who leave formal employment over time by worker characteristics, comparing those who reported earning the minimum wage and those who reported earning in relative wage bin 3 in the previous year in event study regression estimates, based on Equation (15). Panel (a) shows estimates by gender (female in blue and male in red). Panel (b) shows estimates by age group (age 18-30 in blue, age 31-40 in red, age 41-50 in green, and age 51-65 in yellow). Panel (c) shows estimates by skill level (primary in blue, lower secondary in red, upper secondary in green, and tertiary in yellow). Standard errors are clustered at the firm level, 95% confidence intervals are displayed. For more details, see Section 5.

Figure 12: Heterogeneity by Firm Characteristics in Probability of Leaving Formal Employment Over Time



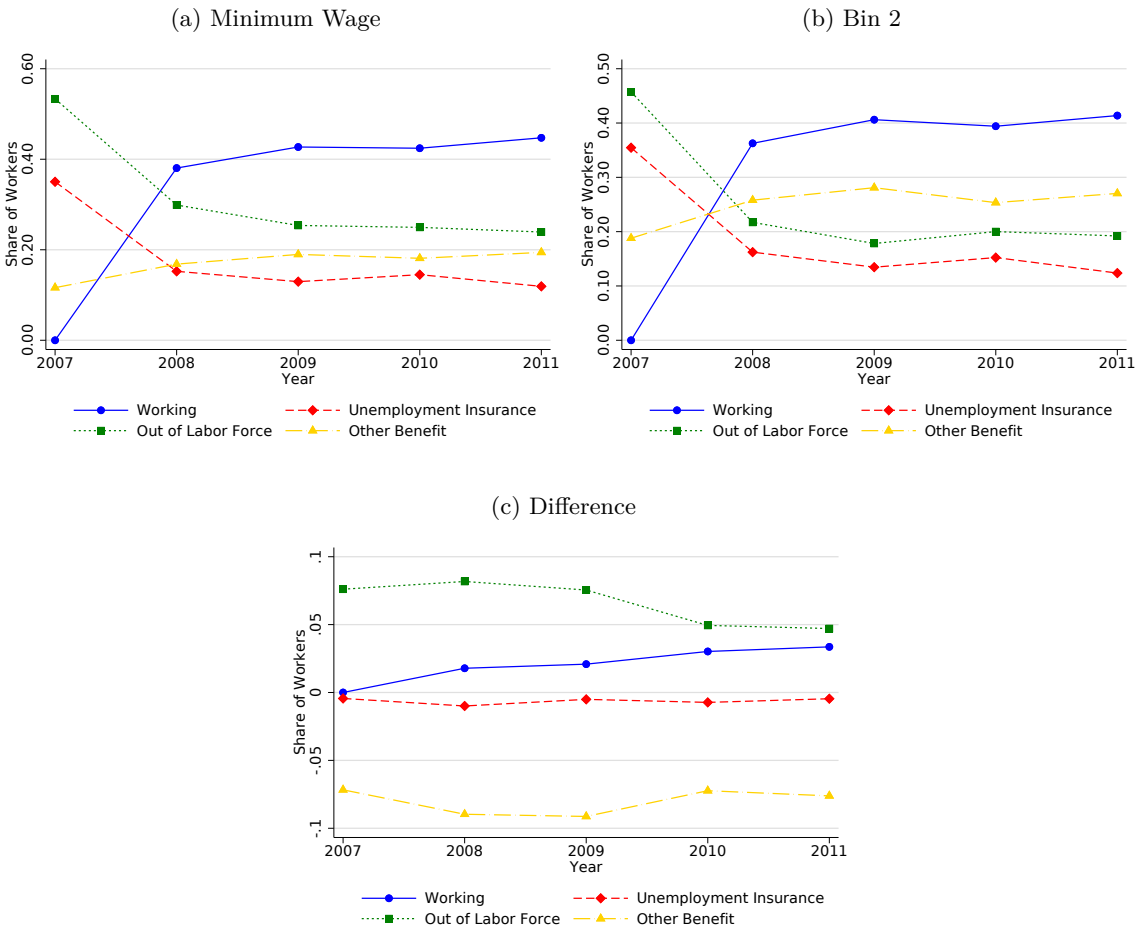
Note: Figure shows the share of private sector employees who leave formal employment over time by firm characteristics, comparing those who reported earning the minimum wage and those who reported earning in relative wage bin 3 in the previous year in event study regression estimates, based on Equation (15). Panel (a) shows estimates by ownership (domestic in blue and foreign in red). Panel (b) shows estimates by observed size (0-5 in blue, 6-50 in red, 51-125 in green, and more than 126 in yellow). Panel (c) shows estimates by industry (Agriculture in blue, Mining & Manufacturing in red, Construction in green, Trade in yellow, Transportation in orange, and Accommodation & Food in purple). Standard errors are clustered at the firm level, 95% confidence intervals are displayed. For more details, see Section 5.

Figure 13: Heterogeneity by Firm Total Factor Productivity in Probability of Leaving Formal Employment Over Time



Note: Figure shows the share of private sector employees who leave formal employment over time by total factor productivity, comparing those who reported earning the minimum wage and those who reported earning in relative wage bin 3 in the previous year in event study regression estimates, based on Equation (15). We show estimates for workers of firms that fall in quartile 1 of the measure in blue, estimates for workers of firms that fall in quartile 2 of the measure in red, estimates for workers of firms that fall in quartile 3 of the measure in green, and estimates for workers of firms that fall in quartile 4 of the measure in yellow. Standard errors are clustered at the firm level, 95% confidence intervals are displayed. For more details, see Section 5.

Figure 14: Future Labor Market Status of Workers Leaving Formal Employment Between December 2005 and January 2007



Note: Figure shows the labor market status by year of those private sector employees who leave formal employment by January 2007 (but worked in December 2005). Panel (a) shows workers who reported earning the minimum wage in December 2005, Panel (b) shows workers who reported earning in relative wage bin 2 in December 2005, and Panel (c) shows the difference. We show the share working in blue, the share receiving unemployment payments in red, the share out of the labor force and not observed in our data as green, and the share receiving other benefits (pensions, disability payments, family payments, other transfers) in gold.

Table 1: Monthly Minimum Wages and Guaranteed Wage Minima by Year

Year	Minimum Wage				GMW	PPP
	Gross	Net	TLC	Tax Wedge (%)	Gross	
	(1)	(2)	(3)	(4)	(5)	(6)
1997	17,000	15,045	26,450	43.1		77.5
1998	19,500	17,258	30,297	43.0		88.4
1999	22,500	18,188	34,538	47.3		95.1
2000	25,500	20,213	38,963	48.1		97.6
2001	40,000	30,000	58,400	48.6		103.6
2002	50,000	36,750	71,250	48.4		104.7
2003	50,000	42,750	70,200	39.1		112.4
2004	53,000	45,845	74,205	38.2		117.3
2005	57,000	49,305	79,295	37.8		122.2
2006	62,500	54,063	85,388	36.7	68,000	124.5
2007	65,500	53,915	89,393	39.7	75,400	129.0
2008	69,000	56,190	94,065	40.3	86,300	128.9
2009	71,500	57,815	97 403	40.6	87,500	127.7
2010	73,500	60,236	94,448	36.2	89,500	122.9
2011	78,000	60,600	100,230	39.5	94,000	122.0
2012	93,000	60,915	119,505	49.0	108,000	122.6
2013	98,000	64,190	125,930	49.0	114,000	121.8
2014	101,500	66,483	130,428	49.0	118,000	125.7
2015	105,000	68,775	134,925	49.0	122,000	128.7
2016	111,000	73,815	142,635	48.2	129,000	131.2
2017	127,500	84,788	157,463	46.2	161,000	135.1
2018	138,000	91,770	167,670	45.3	180,500	138.6

Note: Table collects nominal monthly minimum wages in column (1) and guaranteed wage minima (column 5) in Hungarian forints. For the minimum wage, it also tabulates the net amount (column 2) assuming a single full-time full-year worker earning the minimum wage throughout and not taking advantage of other income tax deductions or credits. The total labor cost towards the employer is listed in column (3), and column (4) tabulates the corresponding tax wedge between columns 2 and 3. Source: page 285 of Fazekas (2019), using calculations of Ágota Scharle. Column (6) lists the Purchasing Power Parity between 1 USD and Hungarian forints for actual individual consumption, as reported by the OECD. Our analysis covers 2003-2011.

Table 2: Tax and Social Security Contribution Rates by Year

		Employee			Employer		
Year	Tax	Pension Fund	Health Insurance	Labor Market Fund	Pension Fund	Health Insurance	Unemployment Insurance
2003	0-650,000: 20% 650,000-1,350,000: 30% 1,350,000-: 40%	8.5%	3%	3%	18%	11%	1%
2004	0-800,000: 18% 800,000-1,500,000: 26% 1,500,000-: 38%	8.5%	4%	3%	18%	11%	1%
2005	0-1,500,000: 18% 1,500,000: 38%	8.5%	4%	3%	18%	11%	1%
2006	0-1,550,000: 18% 1,550,000-: 36%	8.5%	4%	3%	18%	11%	1%
2007	0-1,700,000: 18% 1,700,000-: 36%	8.5%	7%	3%	21%	8%	1.5%
2008	0-1,700,000: 18% 1,700,000-: 36%	9.5%	6%	3%	24%	5%	1.5%
2009	0-1,900,000: 18% 1,900,000-: 36%	9.5%	6%	3%	24%	5%	1.5%
2010	0-5,000,000: 17% 5,000,000-: 32%	9.5%	6%	1%	24%	2%	1.5%
2011	16%	10%	6%	1%	24%	2%	1.5%

Note: Table shows tax and social security contribution rates by year.

Table 3: Summary Statistics of Individual Characteristics

	Private Sector Employees		Self-employed		Public Sector Employees	
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.
Age	38.45	10.77	41.93	9.71	42.17	10.18
Share Male	0.56	0.50	0.65	0.48	0.27	0.44
Monthly Earnings (HUF)	154,780	313,188	72,932	786,264	191,774	172,654
Skill Level						
Primary	0.13				0.14	
Lower Secondary	0.49				0.12	
Upper Secondary	0.26				0.33	
Tertiary	0.12				0.41	
Person-Year Observations	8,946,562		960,638		2,496,331	
Unique Individuals	1,867,828		273,879		506,534	

Note: Table shows summary statistics by sector. The sample pools years 2003-2011. Skill level is missing for the self-employed because we are unable to impute it based on occupation characteristics.

Table 4: Summary Statistics of Firm Indicators

	Weighted by Firm Size			Unweighted		
	Mean	Std. Dev.	Median	Mean	Std. Dev.	Median
Observed Firm Size	427	1,382	28	6.00	49.22	2
Foreign Ownership	0.33	0.47	0	0.07	0.26	0
Total Factor Productivity	0.77	1.03	0.77	0.03	0.90	0.09

Note: Table collects summary statistics on private sector firms in the pooled sample of years 2003–2011. There are 398,906 firms in that sample.

Table 5: Share of Workers Reporting Earning at the Double Minimum Wage Before and After the Reform

	(1)	(2)
Post × Private Sector Employee	0.023***	0.023***
	[0.001]	[0.001]
Post × Self-Employed	0.114***	0.115***
	[0.001]	[0.001]
Post × Workers of Public Firms	0.017**	0.017**
	[0.008]	[0.008]
Controls		×
N	12,385,920	12,328,514

Robust standard errors clustered at the firm level in brackets
*** p<0.01, ** p<0.05, * p<0.1

Note: Table shows difference-in-differences regression estimates of the change between the period before the introduction of the double minimum wage rule (2004-2006) and the period after the introduction of the double minimum wage rule (2007-2010) in the probability of reporting at the double minimum wage for private sector employees and the self-employed vs public sector employees, based on Equation (14). In column (1) we show estimates with no additional controls. In column (2) we show estimates controlling for gender, age group, and location (capital vs not). Standard errors are clustered at the firm level.

Table 6: Share of Workers Who Leave Formal Employment in 2007

(a) Private Sector Employees

Reference bin:	(1) Bin 2	(2) Bin 2	(3) Bin 3	(4) Bin 3	(5) Bin 4	(6) Bin 4
2007 × Minimum Wage	0.032***	0.032***	0.040***	0.041***	0.034***	0.036***
	[0.002]	[0.002]	[0.003]	[0.003]	[0.003]	[0.003]
Controls		×		×		×
N	2,003,193	1,990,559	1,712,067	1,701,136	1,593,756	1,583,331

(b) Public Sector Employees

Reference bin:	(1) Bin 2	(2) Bin 2	(3) Bin 3	(4) Bin 3	(5) Bin 4	(6) Bin 4
2007 × Minimum Wage	0.014	0.015	0.007	0.010	0.006	0.010
	[0.015]	[0.014]	[0.014]	[0.013]	[0.014]	[0.013]
Controls		×		×		×
N	108,341	107,919	154,190	153,693	164,824	164,381

Robust standard errors, clustered at the firm level in brackets
*** p<0.01, ** p<0.05, * p<0.1

Note: Table shows regression estimates of the probability of leaving formal employment in 2007 among those reporting at the minimum wage in the previous year relative to those reporting in one of the relative wage bins above the minimum wage, based on Equation (15). Panel (a) shows estimates for private sector employees, Panel (b) shows estimates for public sector employees. In columns (1) and (2), the comparison group for workers reporting at the minimum wage in the prior year are workers reporting in relative wage Bin 2. In columns (3) and (4) , the comparison group for workers reporting at the minimum wage in the prior year are workers reporting in relative wage Bin 3. In columns (5) and (6) , the comparison group for workers reporting at the minimum wage in the prior year are workers reporting in relative wage Bin 4. For more details on our relative wage definitions see Section 5. In columns (1), (3), and (5) we show estimates with no additional controls. In columns (2), (4), and (6), we show estimates controlling for gender, age group, and location (capital vs not). Standard errors are clustered at the firm level.

Appendix

A Proofs and Derivations

A.1 Characterizing Bunching at the Minimum Wage

The Karush-Kuhn-Tucker conditions are the following, with corresponding complementary slackness for the nonnegative multipliers and the respective nonnegativity constraints.

$$\max_{w,e} V = f(w \mid \theta) - w - \tau \cdot (w - e) - \rho p \tau e - g(e) \tag{17}$$

$$w - e - M \geq 0, \ (\lambda) \tag{18}$$

$$e \geq 0, \ (\mu) \tag{19}$$

$$V \geq 0 \ (\nu). \tag{20}$$

The first-order conditions are:

$$\lambda + (1 + \nu) \left(f_w(w \mid \theta) - (1 + \tau) \right) = 0, \tag{21}$$

$$-\lambda + \mu + (1 + \nu) \left(\tau(1 - \rho p) - g'(e) \right) = 0. \tag{22}$$

.

The following cases characterize the solutions:

Case 1: no constraint binding ($\lambda = \mu = \nu = 0$). These are firms (with $\theta_1 \in \Theta_1$) operating profitably with pay and reported pay over the minimum. With all multipliers equal to zero, we can show their productivity is higher than any of the other groups.

The first-order conditions in this case are:

$$f_w(w_1 \mid \theta_1) = (1 + \tau) \tag{23}$$

$$\tau(1 - \rho p) = g'(e_1). \tag{24}$$

Case 2: reporting constraint binds only ($\mu = \nu = 0$, $w - e = M$). This is similar to the case of

Subsection 3.1, for $\theta_2 \in \Theta_2$:

The first-order conditions in this case are:

$$f_w(w_2 \mid \theta_2) + \lambda_2 = (1 + \tau) \tag{25}$$

$$\tau(1 - \rho p) = \lambda_2 + g'(e_2). \tag{26}$$

Lemma 1. $\theta_2 \leq \theta_1$, $\forall \theta_2 \in \Theta_2, \theta_1 \in \Theta_1$.

Proof. From $g'(e_2) \leq g'(e_1)$, it follows that $e_2 \leq e_1$. Thus, $w_2 = M + e_2 \leq M + e_1 \leq w_1$. Also, $f_w(w_1 \mid \theta_2) \leq f_w(w_2 \mid \theta_2) \leq f_w(w_1 \mid \theta_1)$, therefore, $\theta_2 \leq \theta_1$. □

Case 3a: evasion constraint binds only ($\lambda = \nu = 0$, $e = 0$). This implies that $g'(0) = \tau(1-\rho p)+\mu$. The assumption of $g'(0) = 0$ renders this case moot.

Case 3: evasion and minimum wage constraints both bind for profitable firms ($\nu = 0$). This is a case with $e = 0$ but $w = M$, for $\theta_3 \in \Theta_3$.

The first-order conditions are now:

$$f_w(M \mid \theta_3) + \lambda_3 = (1 + \tau) \tag{27}$$

$$\tau(1 - \rho p) = \lambda_3 + g'(0) - \mu_3 = \lambda_3 - \mu_3. \tag{28}$$

Lemma 2. $\theta_3 \leq \theta_2$, $\forall \theta_3 \in \Theta_3, \theta_2 \in \Theta_2$.

Proof. From the first-order conditions, $\lambda_3 \geq \lambda_2$. Thus, $f_w(w_2 \mid \theta_3) \leq f_w(M \mid \theta_3) \leq f_w(w_2 \mid \theta_2)$. Therefore, $\theta_3 \leq \theta_2$. □

The remaining cases cover the firm (job) barely breaking even. Depending on costs and technology, this could arise at any of the three cases discussed so far — and by monotonicity, it would render all other cases with lower productivity moot.

Case 4: all constraints bind. The firm barely breaks even with $w = M$ and $e = 0$. As $g(0) = 0$, this pins down a single θ_4 for which $f(M \mid \theta_4) - M - \tau M = 0$.

Lemma 3. $\theta_4 \leq \theta_3$.

Proof. $f(M \mid \theta_3) \geq 0 = f(M \mid \theta_4)$, therefore, $\theta_4 \leq \theta_3$. □

From the above lemmas it follows that $\theta_4 \leq \theta_3 \leq \theta_2 \leq \theta_1$. Have the three relevant intervals of $\Theta_3, \Theta_2, \Theta_1$ demarcated by points θ_4, θ_{32}, and θ_{21}. (Θ_1 is open from above.) Figure 2 illustrates the productivity categories.

A.2 The First Derivative of Welfare with Respect to the Minimum Wage

Proof. Proof of Proposition 2 Raising the minimum wage affects the three groups characterized at the end of Section 3 and the previous Appendix Section A.1 as follows:

1. Where the constraint is ineffective, lax ($\lambda = 0$), behavior does not change.

$$\frac{\mathrm{d}}{\mathrm{d}M}\int_{\theta_{21}}^{\infty} \alpha(\theta)V(\theta) + \beta(\theta)w(\theta) + \gamma(\theta)(\tau(w(\theta) - e(\theta)) + \rho p\tau e(\theta))\,\mathrm{d}\theta = \int_{\theta_{21}}^{\infty} 0\,\mathrm{d}\theta - \frac{\mathrm{d}\theta_{21}}{\mathrm{d}M}\left(\alpha(\theta_{21})V(\theta_{21}) + \beta(\theta_{21})w(\theta_{21}) + \gamma(\theta_{21})(\tau(w(\theta_{21}) - e(\theta_{21})) + \rho p\tau e(\theta_{21}))\right)$$

2. For evaders bunching at the minimum wage,

$$\begin{aligned}\frac{\mathrm{d}}{\mathrm{d}M}\int_{\theta_{32}}^{\theta_{21}} \alpha(\theta)V(\theta) + \beta(\theta)w(\theta) + \gamma(\theta)(\tau M + \rho p\tau e(\theta))\,\mathrm{d}\theta = & \\ \int_{\theta_{32}}^{\theta_{21}} \left(-\alpha(\theta)\lambda(\theta) + \beta(\theta)\frac{\mathrm{d}w(\theta)}{\mathrm{d}M} + \gamma(\theta)\tau + \gamma(\theta)\rho p\tau\frac{\mathrm{d}e(\theta)}{\mathrm{d}M}\right)\mathrm{d}\theta + & \\ + \frac{\mathrm{d}\theta_{21}}{\mathrm{d}M}\left(\alpha(\theta_{21})V(\theta_{21}) + \beta(\theta_{21})w(\theta_{21}) + \gamma(\theta_{21})(\tau M + \rho p\tau e(\theta_{21}))\right) & \\ - \frac{\mathrm{d}\theta_{32}}{\mathrm{d}M}\left(\alpha(\theta_{32})V(\theta_{32}) + \beta(\theta_{32})w(\theta_{32}) + \gamma(\theta_{32})(\tau M + \rho p\tau e(\theta_{32}))\right), & \end{aligned}$$

where we use the envelope theorem for $\frac{\mathrm{d}V(\theta)}{\mathrm{d}M} = -\lambda(\theta)$.

3. For true minimum wage jobs,

$$\frac{\mathrm{d}}{\mathrm{d}M}\int_{\theta_4}^{\theta_{32}} \alpha(\theta)V(\theta)+\beta(\theta)M+\gamma(\theta)\tau M\,\mathrm{d}\theta = \int_{\theta_4}^{\theta_{32}} \left(-\alpha(\theta)\lambda(\theta)+\beta(\theta)+\gamma(\theta)\tau\right)\mathrm{d}\theta + \\ + \frac{\mathrm{d}\theta_{32}}{\mathrm{d}M}\left(\alpha(\theta_{32})V(\theta_{32})+\beta(\theta_{32})M+\gamma(\theta_{32})\tau M\right) - \frac{\mathrm{d}\theta_4}{\mathrm{d}M}\left(\beta(\theta_4)M+\gamma(\theta_4)\tau M\right)$$

Notice that because welfare is a continuous function of productivity even at the thresholds of different cases, the sum of these terms are not affected by the changes in the thresholds. Formally:

$$\alpha(\theta_{21})V(\theta_{21})+\beta(\theta_{21})w(\theta_{21})+\gamma(\theta_{21})(\tau(w(\theta_{21})-e(\theta_{21}))+\rho p\tau e(\theta_{21})) = \\ = \alpha(\theta_{21})V(\theta_{21})+\beta(\theta_{21})w(\theta_{21})+\gamma(\theta_{21})(\tau M+\rho p\tau e(\theta_{21})) \quad (29)$$

as $w-e=M$ at θ_{21} and the wage and evasion schedule (not distinguished here) also solve the same problem at this point as this is the point with a zero multiplier even though its constraint still binds ($\lambda=0$), as complementary slackness allows. Similarly,

$$\alpha(\theta_{32})V(\theta_{32})+\beta(\theta_{32})w(\theta_{32})+\gamma(\theta_{32})(\tau M+\rho p\tau e(\theta_{32})) = \\ = \alpha(\theta_{32})V(\theta_{32})+\beta(\theta_{32})M+\gamma(\theta_{32})\tau M \quad (30)$$

as $w=M$ and $e=0$ at θ_{32} and everything equals because the two cases coincide with $\mu=0$ (even though its constraint is not lax).

Using that for evaders bunching at the minimum wage, $\beta(\theta)\frac{\mathrm{d}w(\theta)}{\mathrm{d}M}=\beta(\theta)+\beta(\theta)\frac{\mathrm{d}e(\theta)}{\mathrm{d}M}$, in total, the welfare changes from a marginal increase of the minimum wage add up to

$$\frac{\mathrm{d}W}{\mathrm{d}M} = \int_{\theta_4}^{\theta_{21}}\left(-\alpha(\theta)\lambda(\theta)+\beta(\theta)+\gamma(\theta)\tau\right)\mathrm{d}\theta + \int_{\theta_{32}}^{\theta_{21}}\left(\beta(\theta)+\gamma(\theta)\rho p\tau\right)\frac{\mathrm{d}e(\theta)}{\mathrm{d}M}\,\mathrm{d}\theta \\ - \frac{\mathrm{d}\theta_4}{\mathrm{d}M}\left(\beta(\theta_4)M+\gamma(\theta_4)\tau M\right). \quad (31)$$

□

A.3 The Cross-Derivative of Welfare with Respect to the Minimum Wage and Audit Probabilities

Proof. Proof of Theorem 1 First, ponder the cross partial derivative:

$$\begin{aligned}\frac{\mathrm{d}^2 W}{\mathrm{d}M\,\mathrm{d}p} = &\int_{\theta_4}^{\theta_{21}} \left(-\alpha(\theta)\frac{\mathrm{d}\lambda}{\mathrm{d}p}\right)\mathrm{d}\theta + \\ &+ \frac{\mathrm{d}\theta_{21}}{\mathrm{d}p}\left(-\alpha(\theta_{21})\lambda(\theta_{21}) + \beta(\theta_{21}) + \gamma(\theta_{21})\tau\right) - \frac{\mathrm{d}\theta_4}{\mathrm{d}p}\left(-\alpha(\theta_4)\lambda(\theta_4) + \beta(\theta_4) + \gamma(\theta_4)\tau\right) + \\ &+ \int_{\theta_{32}}^{\theta_{21}} \left(\beta(\theta) + \gamma(\theta)\rho p\tau\right)\frac{\mathrm{d}^2 e}{\mathrm{d}M\,\mathrm{d}p} + \gamma(\theta)\rho\tau\frac{\mathrm{d}e}{\mathrm{d}M}\,\mathrm{d}\theta + \frac{\mathrm{d}\theta_{21}}{\mathrm{d}p}\left(\beta(\theta_{21}) + \gamma(\theta_{21})\rho p\tau\right)\frac{\mathrm{d}e}{\mathrm{d}M} - \\ &- \frac{\mathrm{d}\theta_{32}}{\mathrm{d}p}\left(\beta(\theta_{32}) + \gamma(\theta_{32})\rho p\tau\right)\frac{\mathrm{d}e}{\mathrm{d}M} - \frac{\mathrm{d}^2\theta_4}{\mathrm{d}M\,\mathrm{d}p}\left(\beta(\theta_4)M + \gamma(\theta_4)\tau M\right). \quad (32)\end{aligned}$$

This simplifies, because $\frac{\mathrm{d}^2\theta_4}{\mathrm{d}M\,\mathrm{d}p} = 0$ with the break-even firm conducting no evasion (and dropping the notation for θ-specific weights, as we already did for derivatives):

$$\begin{aligned}\frac{\mathrm{d}^2 W}{\mathrm{d}M\,\mathrm{d}p} = &\int_{\theta_4}^{\theta_{21}} \left(-\alpha\frac{\mathrm{d}\lambda}{\mathrm{d}p}\right)\mathrm{d}\theta + \frac{\mathrm{d}\theta_{21}}{\mathrm{d}p}\left(-\alpha\lambda + \beta + \gamma\tau\right) - \frac{\mathrm{d}\theta_4}{\mathrm{d}p}\left(-\alpha\lambda + \beta + \gamma\tau\right) + \\ &+ \int_{\theta_{32}}^{\theta_{21}} \left(\beta + \gamma\rho p\tau\right)\frac{\mathrm{d}^2 e}{\mathrm{d}M\,\mathrm{d}p} + \gamma\rho\tau\frac{\mathrm{d}e}{\mathrm{d}M}\,\mathrm{d}\theta + \frac{\mathrm{d}\theta_{21}}{\mathrm{d}p}\left(\beta + \gamma\rho p\tau\right)\frac{\mathrm{d}e}{\mathrm{d}M} - \frac{\mathrm{d}\theta_{32}}{\mathrm{d}p}\left(\beta + \gamma\rho p\tau\right)\frac{\mathrm{d}e}{\mathrm{d}M}. \quad (33)\end{aligned}$$

This simplifies further as $\left.\frac{\mathrm{d}e(\theta)}{\mathrm{d}M}\right|_{\theta=\theta_{32}} = 0$ for zero evasion with marginal cost of zero. Also, $\lambda(\theta_{21}) = 0$ by definition. The shadow price of the minimum wage does not change for firms with no evasion, so $\frac{\mathrm{d}\lambda}{\mathrm{d}p} = 0; \forall\theta \in [\theta_4, \theta_{32}]$. $\frac{\mathrm{d}\theta_4}{\mathrm{d}p} = 0$ as evasion (and detection, and fines) do not enter the calculus for the marginal firm breaking even, as we assumed that some firms still operate truly paying the minimum wage (and they must be less productive than evaders). Also, $\mathrm{d}^2 e/\,\mathrm{d}M\,\mathrm{d}p = 0$.

The cross-partial reads thus:

$$\frac{\mathrm{d}^2 W}{\mathrm{d}M\,\mathrm{d}p} = \int_{\theta_{32}}^{\theta_{21}} \left(-\alpha\frac{\mathrm{d}\lambda}{\mathrm{d}p}\right)\mathrm{d}\theta + \frac{\mathrm{d}\theta_{21}}{\mathrm{d}p}\left(\beta + \gamma\tau\right) + \int_{\theta_{32}}^{\theta_{21}} \gamma\rho\tau\frac{\mathrm{d}e}{\mathrm{d}M}\,\mathrm{d}\theta + \frac{\mathrm{d}\theta_{21}}{\mathrm{d}p}\left(\beta + \gamma\rho p\tau\right)\frac{\mathrm{d}e}{\mathrm{d}M}. \quad (34)$$

$\frac{\mathrm{d}\theta_{21}}{\mathrm{d}p} < 0$, as more firms (jobs) operate with smaller, non-binding evasion when enforcement is stricter (e_1 is lower when p is higher). Formally, from the optimality conditions under case 2, a lower p implies a higher $g'(w(\theta_{21}) - M)$ and thus higher $w(\theta_{21})$ and lower $f_w(w \mid \theta_{21})$. θ_{21} has to increase to still satisfy the equality with $(1 + \tau)$.

Yet evasion and the minimum wage move in opposite direction, but not one-to-one, thus at θ_{21}:

$$\frac{\mathrm{d}\theta}{\mathrm{d}p}(\beta+\gamma\tau)+\frac{\mathrm{d}\theta}{\mathrm{d}p}(\beta+\gamma\rho p\tau)\frac{\mathrm{d}e}{\mathrm{d}M}<\frac{\mathrm{d}\theta}{\mathrm{d}p}(\beta+\gamma\tau)+\frac{\mathrm{d}\theta}{\mathrm{d}p}(\beta+\gamma\rho p\tau)(-1)<$$
$$<\frac{\mathrm{d}\theta}{\mathrm{d}p}(\beta+\gamma\tau)-\frac{\mathrm{d}\theta}{\mathrm{d}p}(\beta+\gamma\cdot 1\cdot 1\cdot\tau)=0, \quad (35)$$

where we used that at θ_{21}, $-1<\frac{\mathrm{d}e(\theta)}{\mathrm{d}M}<0$. To see this, first note that if $M=w-e$ rises, then e and w cannot both rise along, because the first would imply a lower λ, the second a higher, a contradiction. Similarly, e and w both falling is a contradiction as well. Thus, e falls and w rises if M increases. From this, using that $\frac{\mathrm{d}w(\theta)}{\mathrm{d}M}=1+\frac{\mathrm{d}e(\theta)}{\mathrm{d}M}>0$, it follows that $-1<\frac{\mathrm{d}e(\theta)}{\mathrm{d}M}<0$.

For the remaining terms, first see that as $\mathrm{d}e/\,\mathrm{d}M<0$.

All that remains to show that the cross-partial is negative is that the integral in the first term is negative. As $\alpha(\theta)\geq 0$, this is guaranteed if $\mathrm{d}\lambda/\,\mathrm{d}p>0$ for the cases we numbered as Case 2 before, the bunching evaders. For them $\mathrm{d}w=\mathrm{d}e$ which we can use to rearrange the differential of both equations as

$$\frac{\mathrm{d}\lambda}{\mathrm{d}p}=\tau\rho\frac{f_{ww}(w\mid\theta)/g''(e)}{f_{ww}(w\mid\theta)/g''(e)-1}, \quad (36)$$

which is clearly positive as $f_{ww}(w\mid\theta)<0$ and $g''(e)>0$. □

B Audit Statistics

The Hungarian Tax Authority reported aggregate annual audit statistics by some grouping of taxpayers until 2006. Audit levels are defined as the ratio of the number of completed tax audits in a tax year (which corresponds to a calendar year in Hungary) to the number of taxpayers at the end of the previous year. In 2006, the agency reported very high audit levels (Tax and Financial Control Administration of Hungary, 2007): 41.6% among private business entities with legal personality (partnerships, LLCs, private and public companies) and 15.5% among those without, but only 5.9% among government and other organizations and 4.3% among the self-employed and private persons. These levels were relatively stable throughout 2003-2006. These numbers mean that on average, in 2006, firms with legal personality had an audit every 2.5 years, those without every 6.5 years, government and other organizations every 17 years, and self-employed and private persons every 23

years.

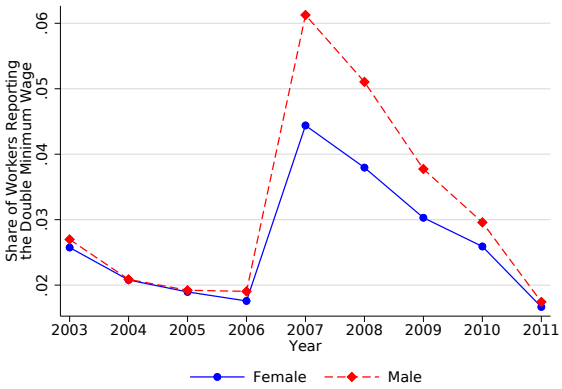
Based on later annual reports, the total number of audits decreased gradually between 2003 and 2007 (from 376 thousand in 2004 to 236 thousand in 2007). Then, there was a marked increase in the number of audits in 2008 (up to 317 thousand), with a decrease afterwards (down to 266 thousand in 2010). (Tax and Financial Control Administration of Hungary, 2019)

It is important to keep in mind that the above audit statistics cover all types of audits the Tax Authority conducts, such as audits to control fulfillment of certain tax obligations, audits of transforming and dissolving entities, net wealth growth audits, etc. Not all audits have the purpose or capacity to reveal underreporting of earnings. In fact, the vast majority (around 80%) of findings of net tax owed was in the value added tax during the analysed period.

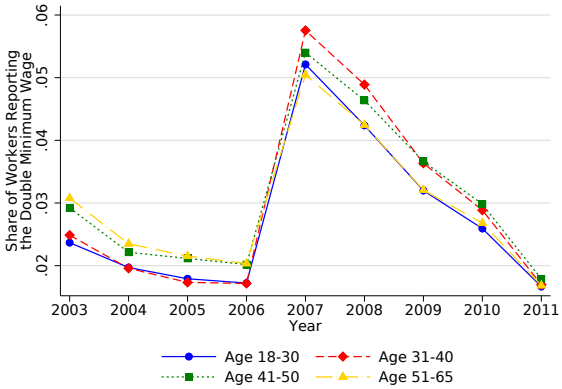
C Appendix Figures

Appendix Figure A1: Share of Private Sector Employees Reporting Earnings at the Double Minimum Wage Over Time by Worker Characteristics

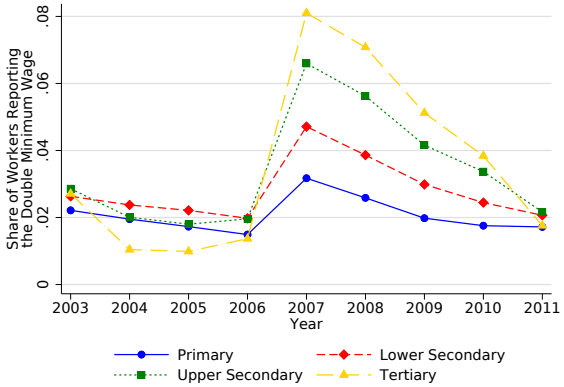
(a) By Gender



(b) By Age



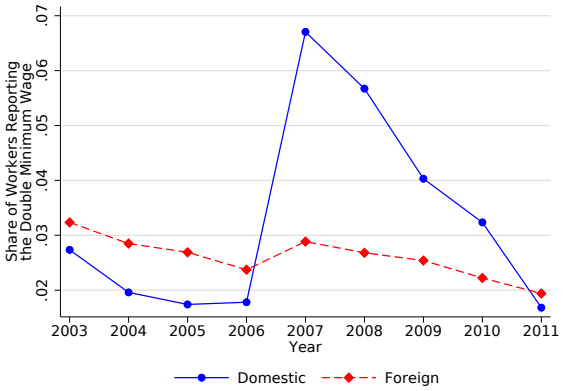
(c) By Skill Level



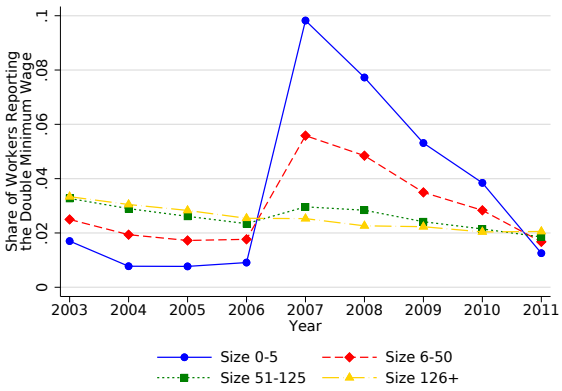
Note: Figure shows the share of private sector employees who report earning the double minimum wage over time by gender, age group, and skill level. Panel (a) shows the share of private sector employees who report earning the double minimum wage for each year by gender (female in blue and male in red). Panel (b) shows the share of private sector employees who report earning the double minimum wage for each year by age group (age 18-30 in blue, age 31-40 in red, age 41-50 in green, and age 51-65 in yellow). Panel (c) shows the share of private sector employees who report earning the double minimum wage for each year by skill level (primary in blue, lower secondary in red, upper secondary in green, and tertiary in yellow). For more details, see Section 5.

Appendix Figure A2: Share of Private Sector Employees Reporting Earnings at the Double Minimum Wage Over Time by Firm Characteristics

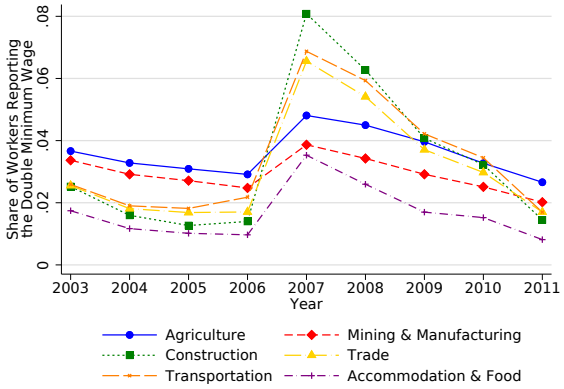
(a) By Ownership



(b) By Size

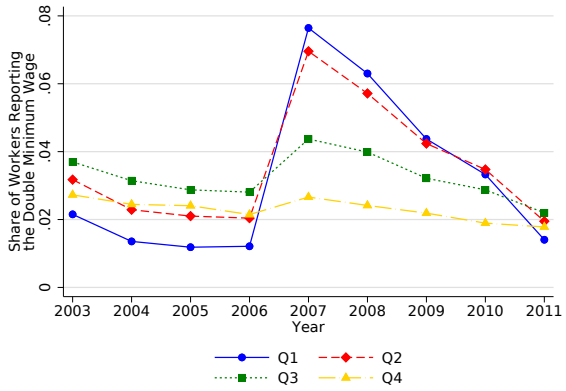


(c) By Industry



Note: Figure shows the share of private sector employees who report earning the double minimum wage over time by ownership, observed size, and industry. Panel (a) shows the share of private sector employees who report earning the double minimum wage for each year by ownership (domestic in blue and foreign in red). Panel (b) shows the share of private sector employees who report earning the double minimum wage for each year by observed size (0-5 in blue, 6-50 in red, 51-125 in green, and more than 126 in yellow). Panel (c) shows the share of private sector employees who report earning the double minimum wage for each year by industry (Agriculture in blue, Mining & Manufacturing in red, Construction in green, Trade in yellow, Transportation in orange, and Accommodation & Food in purple). For more details, see Section 5.

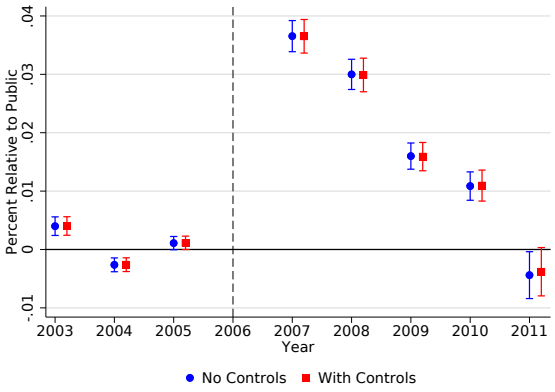
Appendix Figure A3: Share of Workers Reporting Earnings at the Double Minimum Wage Over Time by Total Factor Productivity



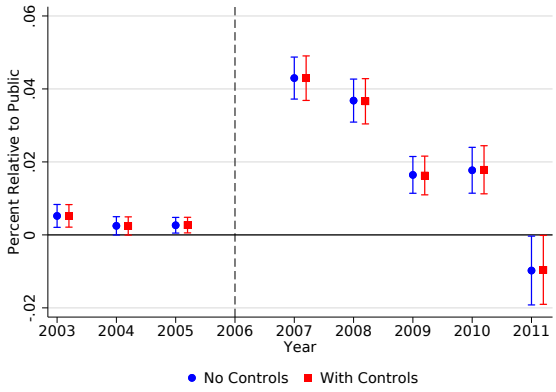
Note: Figure shows the share of workers who report earning double the minimum wage over time by total factor productivity. We show estimates for workers of firms that fall in quartile 1 of TFP in blue, estimates for workers of firms that fall in quartile 2 of TFP in red, estimates for workers of firms that fall in quartile 3 of TFP in green, and estimates for workers of firms that fall in quartile 4 of TFP in yellow. For more details, see Section 5.

Appendix Figure A4: Share of Workers Reporting Earnings at the Double Minimum Wage Over Time

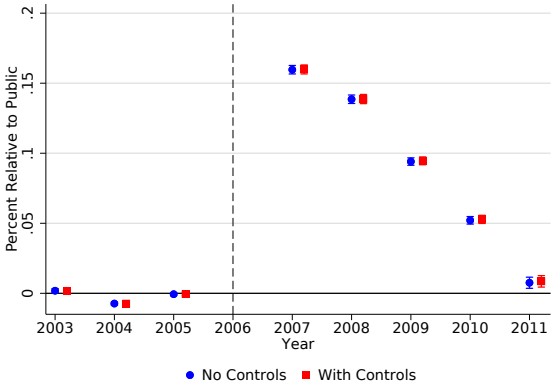
(a) Regression Estimates: Private Sector Employees, 5,000 HUF Wage Bin Definition



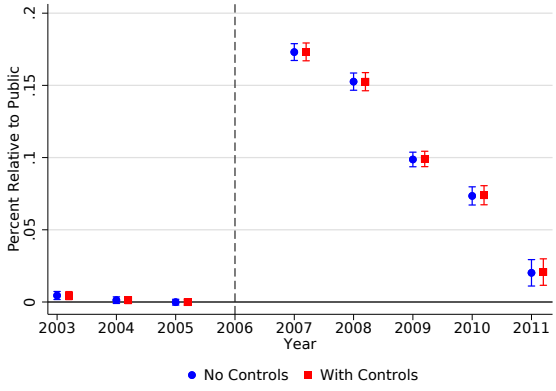
(b) Regression Estimates: Private Sector Employees, 95-105% Wage Bin Definition



(c) Regression Estimates: Self-Employed, 5,000 HUF Wage Bin Definition



(d) Regression Estimates: Self-Employed, 95-105% Wage Bin Definition

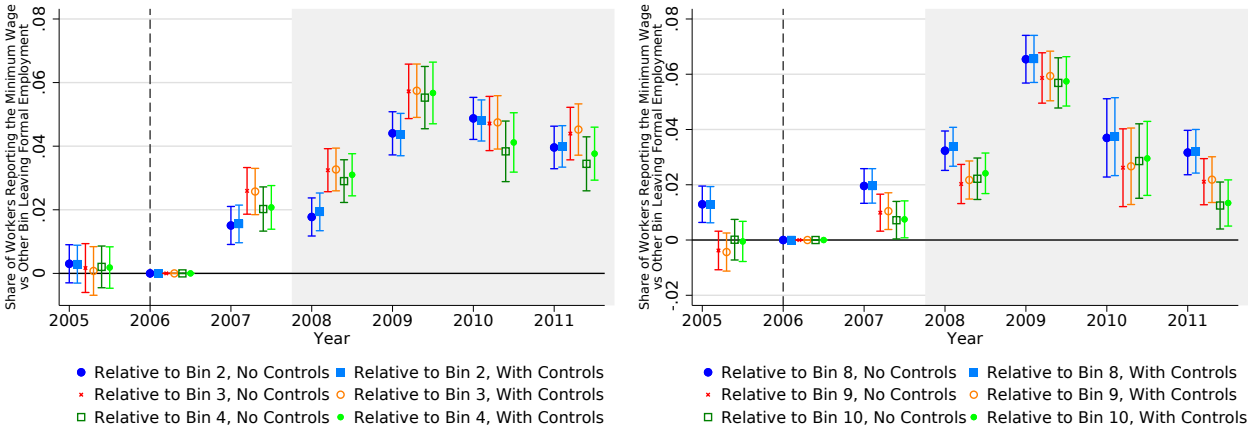


Note: Figure shows the share of workers who report earning double the minimum wage over time by sector. Panels (a) and (b) show event study regression estimates comparing private sector employees to public sector employees, based on Equation (13). Panels (c) and (d) show event study regression estimates comparing the self-employed to public sector employees, based on Equation (13). Panels (a) and (c) repeat results from Panels (b) and (c) of Figure 5, using our standard 5,000 HUF wage bin definition. Panels (b) and (d) show the same results using an alternative wage bin definition, based on annually updated 95-105% interval around the level of the double minimum wage. In each panel, the blue dots show estimates with no additional controls and the red dots show estimates controlling for gender, age group, and location (capital vs not). Standard errors are clustered at the firm level, 95% confidence intervals are displayed. For more details, see Section 5.

Appendix Figure A5: Share of Workers Who Leave Formal Employment by Sector, Wage Bin, and Year

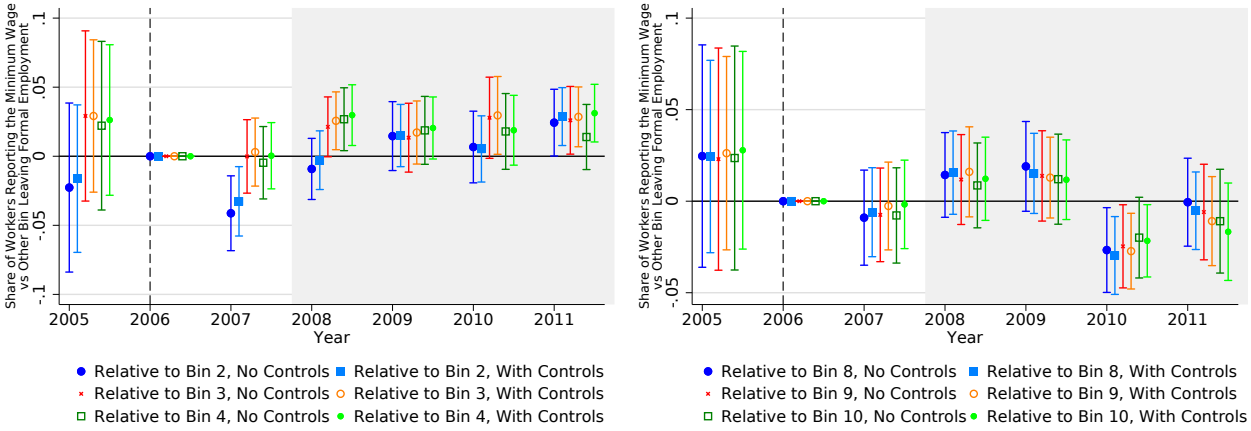
(a) Regression Estimates: Private Sector Employees, Using Wage Bins 2-4 as Reference

(b) Regression Estimates: Private Sector Employees, Using Wage Bins 8-10 as Reference



(c) Regression Estimates: Public Sector Employees, Using Wage Bins 2-4 as Reference

(d) Regression Estimates: Public Sector Employees, Using Wage Bins 8-10 as Reference



Note: Figure shows the share of workers who leave formal employment by January, by sector and wage bin (in December of two years prior) over time. Panels (a) and (b) show private sector employees, Panels (c) and (d) show public sector employees. Repeating our results from Figure 10, Panels (a) and (c) show event study regression estimates comparing those who report earning the minimum wage to those who report earning in relative wage bin 2 (in blue), those who report earning in relative wage bin 3 (in red), and those who report earning in relative wage bin 4 (in green), based on Equation (15). Panels (b) and (d) show event study regression estimates comparing those who report earning the minimum wage to those who report earning in relative wage bin 8 (in blue), those who report earning in relative wage bin 9 (in red), and those who report earning in relative wage bin 10 (in green), based on Equation (15). For each comparison, the first estimate (in a darker color) shows estimates with no additional controls and the second dot (in a lighter color) shows estimates controlling for gender, age group, and location (capital vs not). Standard errors are clustered at the firm level, 95% confidence intervals are displayed. For more details, see Section 5.

Appendix Table A1: Share of Workers Reporting Earning at the Double Minimum Wage Before and After the Reform, 95-105% Definition of the Double Minimum Wage

	(1)	(2)
Post × Private Sector Employee	0.026***	0.026***
	[0.003]	[0.003]
Post × Self-Employed	0.124***	0.125***
	[0.003]	[0.003]
Controls		×
N	12,385,920	12,328,514

Robust standard errors clustered at the firm level in brackets
*** p<0.01, ** p<0.05, * p<0.1

Note: Table shows difference-in-differences regression estimates of the change between the period before the introduction of the double minimum wage rule (2004-2006) and the period after the introduction of the double minimum wage rule (2007-2010) in the probability of reporting at the double minimum wage for private sector employees and the self-employed vs public sector employees, based on Equation (14). This table is analogous to Table 5, but we apply an alternative definition of wage bins. Instead of defining 5,000 HUF wage bins, we create a 95-105% interval around the double minimum wage. In column (1) we show estimates with no additional controls. In column (2) we show estimates controlling for gender, age group, and location (capital vs not). Standard errors are clustered at the firm level.

Appendix Table A2: Share of Workers Who Leave Formal Employment in 2007

(a) Private Sector Employees

Reference bin:	(1) Bin 8	(2) Bin 8	(3) Bin 9	(4) Bin 9	(5) Bin 10	(6) Bin 10
2007 × Minimum Wage	0.031***	0.032***	0.029***	0.030***	0.025**	0.026**
	[0.003]	[0.003]	[0.003]	[0.003]	[0.003]	[0.003]
Controls		×		×		×
N	1,397,225	1,387,777	1,351,921	1,342,823	1,322,537	1,313,606

(b) Public Sector Employees

Reference bin:	(1) Bin 8	(2) Bin 8	(3) Bin 9	(4) Bin 9	(5) Bin 10	(6) Bin 10
2007 × Minimum Wage	-0.013	-0.015	-0.014	-0.016	-0.016	-0.018
	[0.014]	[0.012]	[0.014]	[0.012]	[0.014]	[0.012]
Controls		×		×		×
N	157,904	157,425	151,468	151,061	142,247	141,871

Robust standard errors, clustered at the firm level in brackets
*** p<0.01, ** p<0.05, * p<0.1

Note: Table shows regression estimates of the probability of leaving formal employment in 2007 among those reporting at the minimum wage in the previous year relative to those reporting in one of the relative wage bins above the minimum wage, based on Equation (15). Panel (a) shows estimates for private sector employees, Panel (b) shows estimates for public sector employees. In columns (1) and (2), the comparison group for workers reporting at the minimum wage in the prior year are workers reporting in relative wage Bin 8. In columns (3) and (4) , the comparison group for workers reporting at the minimum wage in the prior year are workers reporting in relative wage Bin 9. In columns (5) and (6) , the comparison group for workers reporting at the minimum wage in the prior year are workers reporting in relative wage Bin 10. For more details on our relative wage definitions see Section 5. In columns (1), (3), and (5) we show estimates with no additional controls. In columns (2), (4), and (6), we show estimates controlling for gender, age group, and location (capital vs not). Standard errors are clustered at the firm level.