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Abstract

We present evidence of the minimum wage effects on labour informality rates in Colombia, where the informality is by far the most serious problem of the labour market. The working population is divided into sixteen groups depending on the age, gender, and educational level. This division allows us to estimate how the relative level of restrictiveness of the minimum wage across different demographic groups affect the probability of being an informal worker. We find that the higher the minimum wage with respect to the 70th percentile wage, the higher will be the probability of being informal. Across different demographic groups, we find sizeable and significant effects for men and women between 18 to 25 years old with lower education levels. Also, less-educated women aged 51 to 65 years old are affected by the minimum wage policy. For these groups, an increase of one percentage point (pp) in the MW ratio increases the probability of having an informal job between 0.35 and 0.99 pp compared to the reference group (men aged 26 to 40 years old and with higher education level) depending on the informality rate measure employed.

***JEL* Classification:** J21, J30, J46, O17.

Key words: *minimum wage, labour informality, heterogeneity.*

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Efectos del salario mínimo en la informalidad laboral: heterogeneidad entre grupos demográficos en Colombia

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Resumen

Presentamos evidencia de los efectos del salario mínimo en las tasas de informalidad laboral en Colombia, donde la informalidad es el problema más grave del mercado laboral. Los trabajadores se dividen en dieciséis grupos según edad, género y nivel educativo. Esta división permite estimar cómo el nivel relativo de restricción del salario mínimo en diferentes grupos demográficos afecta la probabilidad de ser un trabajador informal. Se encuentra que cuanto mayor sea la razón del salario mínimo al salario del percentil 70, mayor será la probabilidad de tener un trabajo informal. Entre los diferentes grupos demográficos, encontramos efectos de magnitud importante y significativos para hombres y mujeres entre 18 y 25 años con bajo nivel educativo. Asimismo, las mujeres de 51 a 65 años con bajo nivel educativo se ven afectadas por la política del salario mínimo. Para estos grupos, un aumento de un punto porcentual (pp) en la razón del salario mínimo aumenta la probabilidad de tener un trabajo informal entre 0,35 y 0,99 pp en comparación con el grupo de referencia (hombres de 26 a 40 años con mayor nivel educativo), dependiendo de la medida de la tasa de informalidad empleada.

Clasificación *JEL*: J21, J30, J46, O17.

Palabras clave: *salario mínimo, informalidad laboral, heterogeneidad.*

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1. Introduction

The effectiveness of the minimum wage (MW) to provide protection to the low-skilled workers is not neat. While there is not a clear consensus on the impact of the MW on employment,[1] various articles have shown that it does have adverse effects on levels of labour informality[2] (see, among many others, Maloney, 2004; Andalón & Pagés, 2008; Arango & Flórez, 2021). In the case of Colombia, apart from the destruction of formal employment (Arango & Rivera, 2021), the most negative effect of the MW seems to be on incentives to create formal jobs or become an informal worker (Mondragón, Peña, & Wills, 2010; Florez; Hermida & Morales, 2022); these effects seem more important than on the structural or the observed unemployment rates (Arango & Flórez, 2020).

The prevalence of labour informality in Colombia was, on average, between 51% and 56% during 2007-2017. According to the information of the Administrative Department of Statistics (*Departamento Administrativo Nacional de Estadística*; DANE, 2018), the proportion of informal workers in 23 cities and metropolitan areas was 47.6% in the last quarter of 2019 as measured by size of employment establishment or 50.6% as measured by lack of affiliation to the pension system. Thus, this phenomenon seems to be more challenging in Colombia than in other similar countries such as Mexico, Chile, Argentina, and Brazil (ILO, 2019). High levels of informality have negative effects on welfare, income distribution, human and physical capital accumulation, long-run growth, and public finance (Goñi, 2013). Thus, it is vital to understand the structural and cyclical causes of this economic phenomenon to create effective public policies to reduce the proportion of informal workers in the country.

The high labour informality rate in Colombia is a complex outcome with different causes mentioned in the literature (see for example, Uribe, 2016; Fernández & Villar, 2016). Arango & Flórez (2021) provided evidence that one of the main determinants of labour informality is the higher level of the MW in comparison to other wages of the economy such as the median or the 70th percentile of the wage distribution. In fact, the Kaitz ratio in Colombia is much higher (over 85 per cent) than the average for

[1] With respect to the employment effects of the minimum wage, the recent academic discussions show no clear cut on this dimension. See among many others Card (1992a, 1992b), Card and Krueger (1994, 1995), Neumark and Wascher (2000, 2008), Doucouliagos and Stanley (2009), De Linde Leonard, Stanley and Doucouliagos (2014), Belmand and Woflson (2014) and Neumark (2018). Clemens (2021), Dube and Lindner (2024), Link (2024) explore adjustment margins other than just employment. In the latter case, Link (2024) shows that firms affected by the introduction of the nationwide minimum wage in 2015 have carried out adjustments in the wage bill by increasing prices instead of focusing on just cutting jobs. Dube and Lindner (2024) also review the impact not only in different margins of the labor market but also in the informal sector (see also Neumark and Mungui-Corella (2021).

[2] According to the International Labor Organization – ILO (2002), informal workers are more vulnerable, as they receive little or no legal or social protection at all. Moreover, they usually lack good job opportunities, job stability, and easy access to education to acquire greater skills.

all OECD countries (about 52 per cent) (see Dube, 2104; Arango & Flórez, 2021, and Arango *et al*., 2022).[3] A high level of the Kaitz ratio implies that the labour productivity of low-skilled workers, those that earn the MW, is high relative to that of the workers with wages in the high percentiles of the distribution. However, given the level of labour informality in Colombia, this premise might not be true; instead, the MW had been artificially raised to a high level that is decoupled from the productivity of less skilled workers. Thus, the greater the distance between the MW and the underlying labour productivity of low-skilled workers, the higher the probability that they will face being fired and subsequently pushed to the informal or uncovered sector.

The objective of this document is to provide evidence of the effects of the exogenous component of MW relative to the 70th percentile of the distribution of the wage distribution (the Minimum Wage Ratio, MW ratio) on the probability of being informal for a worker belonging to different demographic groups. To verify our hypothesis, we exploit the relative level of restrictiveness of the MW legislation in different demographic groups within cities across time. This approach is useful since each group enters in different labour market segments; therefore, the effect of the MW can also be differential by groups. For example, for less-educated young male or female workers, the MW policy may be more binding than for other groups, and therefore the effect on informality may be relatively stronger.

According to Lee (1999), to capture the parameter of interest in our estimation is required that the changes of the MW do not affect the wage for each group in the labour market. However, this assumption does not hold in the case of Colombia for two reasons. First, because the MW is not exogenous; in fact, the regulations stablish the variables that employees, employers, and Government must consider during the annual negotiations to set the new MW. Among these variables we find the inflation of the ending year, the annual variation of productivity, the annual growth of GDP, and so on. Second, given the high proportion of formal workers (about 87%) that earn between one and three minimum wages, changes in the MW affect almost all the wages distribution. Thus, to overcome this problem and estimate the exogenous component of the MW ratio, we follow the approach of Autor, Manning and Smith (2016).

The paper uses monthly information of the Great Integrated Household Survey (*Gran Encuesta Integrada de Hogares*, GEIH its Spanish acronym) from 2007 to 2017 and consider sixteen labour market groups by cities. They are obtained by interacting gender with four age ranges (18 to 25, 26 to 40, 41 to 50 and 51 to 65 years old) and two levels of education (educated and less educated). The main

[3] Ahlfeldt, Roth, and Seidel (2022) find that the when the MW is higher than the 50% of the mean wage, increases in the minimum wage reduce employment at an increasing rate. Some theoretical (Flórez, 2015, 2017) and empirical models use the productivity level to explain labour informality (Maloney, 2004 and Perry, 2007, among others) and its different types such as subsistence informality, induced informality, voluntary and mixed informality (Fernández & Villar, 2016).

contribution of this paper is to find a positive and significant relationship between the exogenous component of MW ratio and the informality rate of different demographics groups. The evidence shows that an exogenous increase on different measures of the MW ratio (related to the wage of the 70th percentile of salaried workers), increases the probability that a worker has an informal occupation. This finding is robust for different specifications. Moreover, the results are significantly higher for some demographic groups, such as young (between 18 to 25 years old) and older (between 51 to 65 years old) men and women with low education.

The article is organized in five sections. Section 2 presents a short discussion of the findings presented in the literature focusing on the results for the case of developing countries as well as evidence on labour informality in Colombia. Section 3 presents the Colombian labour market context and describes the data studied in this paper. Section 4 discusses the empirical framework and the results. Finally, section 5 summarizes the main findings and discusses some policy implications.

2. Related literature

The analysis of the effects of the MW assumes the existence of two productive sectors in the economy, which serves to frame our analysis. One sector which complies with all labour regulations, is called "covered or formal sector" while the other one, the "uncovered or informal sector", does not comply with the existing norms. For example, one of such norms might stipulate the payment of the MW salary in the formal sector, if a firm do not comply with the norm, it would be in the uncovered sector (Welch, 1974; Mincer, 1976). Accordingly, one might expect that some workers who lose their jobs in the covered sector due to the introduction or the increase of a binding MW, will be absorbed by the uncovered sector, thus reducing the average earnings of workers in the latter. Low productivity workers who are looking for a job in the formal sector, will find it more difficult when the MW is higher. Consequently, this model considers informality as a state of exclusion (see Perry, 2007).

The effects of the MW on the level of employment, has been broadly discussed in developed countries where informality is not that important (see Neumark and Wascher, 2008, chapter 3; Card, 1992a and 1992b, and Card & Krueger, 1994 and 1995. According to Neumark (2018, p.4) the MW has adverse effects on employment (see also Neumark & Shirley, 2021). Meta-analyses conducted by Doucouliagos and Stanley (2009), on the other hand, found a negligible effect of the MW on teenage employment in the US. In the same fashion De Linde Leonard, Stanley and Doucouliagos (2014) report no significant effect of the MW on employment for the UK either. Along the same lines Belman and Wolfson (2014, chapter 4). Cenzig, Dube, Lindner and Zipperer (2018) also find negligible effects on jobs (see also

Manning, 2021).[4] Dustman et al. (2022) studied the effects of the introduction of the MW in Germany in 2015, finding no effects on employment while increases in the wages. This response is consistent with the reallocation of workers from less to more efficient firms. Engbom and Moser (2022) also find negligible effects of the MW on employment, and other labour market outcomes. However, it is important to consider that in the United States, the Kaitz index is relatively small (around 55.6% in 2018), while in Colombia, such index is currently above 85%.

However, there is also evidence that the MW produces higher levels of labour informality in developing economies. Andalón & Pagés (2008) found negative impacts of the MW legislation on formal employment as well as an increase in informality in Kenya. These authors report a higher impact on those workers whose wage is closer to the minimum. Thus, given an increase in the MW, employers tend to replace workers with low qualification by those slightly more qualified. Lemos (2009) studies the case of Brazil and finds no evidence of employment effects in neither formal nor informal sector; instead, she found a wage compression effect in both sectors. Millea et al. (2017) evaluate the effect of the sectoral MW legislation introduced in 2002 in South Africa. Their results do not suggest negative effects on formal employment for any demographic group covered by the regulation, although they do for informal workers. According to Broecke, Forti, and Vandeweyer (2017) the average effects found on employment for some developing countries are not that large although, in general there is evidence of negative effects for the most vulnerable groups such as young and low-skilled workers, as well as important effects on informal employment. Ham (2018) analyses the legislation change in Honduras to stablish the effects of the MW across regions, industries, and establishments' size. He finds that an increase in the MW of 10 percent decreases the probability of having a job in the formal sector by 8 percent, while the probability of having a job in the informal sector increases by 5 percent. Lotti *et al*. (2016)[5] present evidence for 59 developing countries of a positive and significant relation between a high level of the MW ratio and the high level of informality. Their results show that a one pp increase in the MW ratio is associated with a 0.204 pp increase in the informality measured as "self-employment rate."[6] Recently, Dube and Lindner (2024) refer marginally to the effects of the MW on wage compression, inequality and informality in developing countries and suggest that the results do not differ from developed countries. Moreover, some

[4] With a search and matching model, Brown et al. (2014) show that larger wages reduce firms' job offer rates while raise workers' acceptance rates. This result is particularly important for the case of Colombia.

[5] Our strategy has some similarities with that of Lotti et al. (2016), however, instead of exploiting the relative level of restrictiveness of the MW legislation in different countries, we use the level of restrictiveness of the MW in different demographic groups in the Colombian labour market. Additionally, we construct an exogenous measure of the MW ratio.

[6] The authors define informality as the share of self-employed and family workers, who are not covered by minimum wage legislation. This measure excludes those who work in agriculture sector.

evidence for the case of Colombia have also find a negative effect of the MW on formal job creation rates (see Florez, Hermida, & Morales, 2022; Arango, Garcia, Posso, 2025).

3. Colombian labour market context and data

In Colombia, informality characterizes legal activities that do not comply with requirements established in the Labour Code (*Código Sustantivo del Trabajo*, in Spanish). The definitions of informality used in this paper follows the official definition used by the DANE called "informality rate by firm's size", according to the first measure, a job is regarded as informal when it corresponds to a firm with a maximum of five employees (comprising all plants), including the employer.[7] Apart from these workers, this measure also includes family workers without payment, domestic workers, self-employment workers (except those with a bachelor's degree) and employers. The second measure is based on workers who do not contribute to the social security (pension or health systems). There are other measures of labour informality based on workers who receive a payment below the MW or those who work a number of hours greater than the legally established (Castells, Portes, & Benton, 1989; ILO, 1972; Mondragón, Peña, & Wills, 2013), that we are not analysing in this paper.

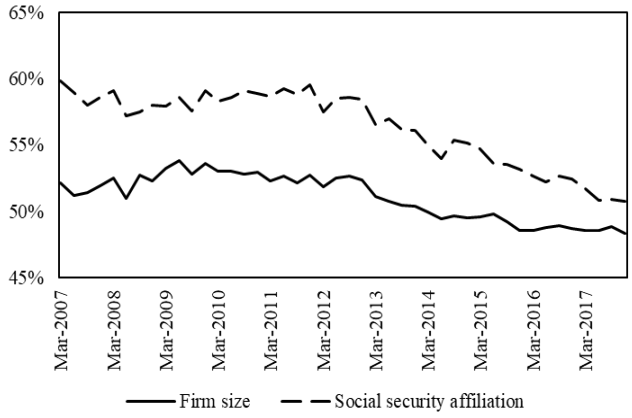
Colombia has a very long tradition of being a country with a high and persistent labour informality rate (see ILO, 2019).[8] To measure the level of informality we use the GEIH published by the DANE, from 2007 to 2017 for the 23 main cities in Colombia at monthly frequency. These cities are Armenia, Barranquilla, Bogotá, Bucaramanga, Cali, Cartagena, Cúcuta, Florencia, Ibagué, Manizales, Medellín, Montería, Neiva, Pasto, Pereira, Popayán, Quibdó, Riohacha, Santa Marta, Sincelejo, Tunja, Valledupar and Villavicencio. Figure 1 presents the evolution of aggregate labour informality rate between 2007 and 2017 computed as the ratio of informal workers over the occupied labour force in all 23 main cities.[9] Even though, it shows a declining trend, at the end of 2017, 48.4 percent of workers were informal, according to the establishment's size definition and 50.8 percent according to the affiliation failure to the pension or health system definition.

The declining trend of the informality rates have been achieved not only thanks to the economic growth during this period, but also to the important effort of the Government in the implementation of the 2012 tax reform, which reduced the non-wage labour cost in 13.5 pp, from about 55.6 percent to 41.8 percent. Even though it is difficult to know with precision how many formal jobs were created, some

[7] Ten workers until 2009.
[8] See for example: https://www.ilo.org/americas/programas-y-proyectos/WCMS_614453/lang--es/index.htm.
[9] The term "occupied" is used to include both workers employed in the formal sector and those working as informal workers; this is so since an important fraction of informal workers is self-employed. These are not employees in the usual sense.

recent research (Bernal, Eslava, Meléndez, & Pinzón, 2017; Fernández & Villar, 2017; Morales & Medina, 2016; Osorio, 2016), suggests that such reform allowed the creation of between 200.000 and 600.000 formal jobs.

Figure 1. Informality rate in Colombia
Twenty-three cities



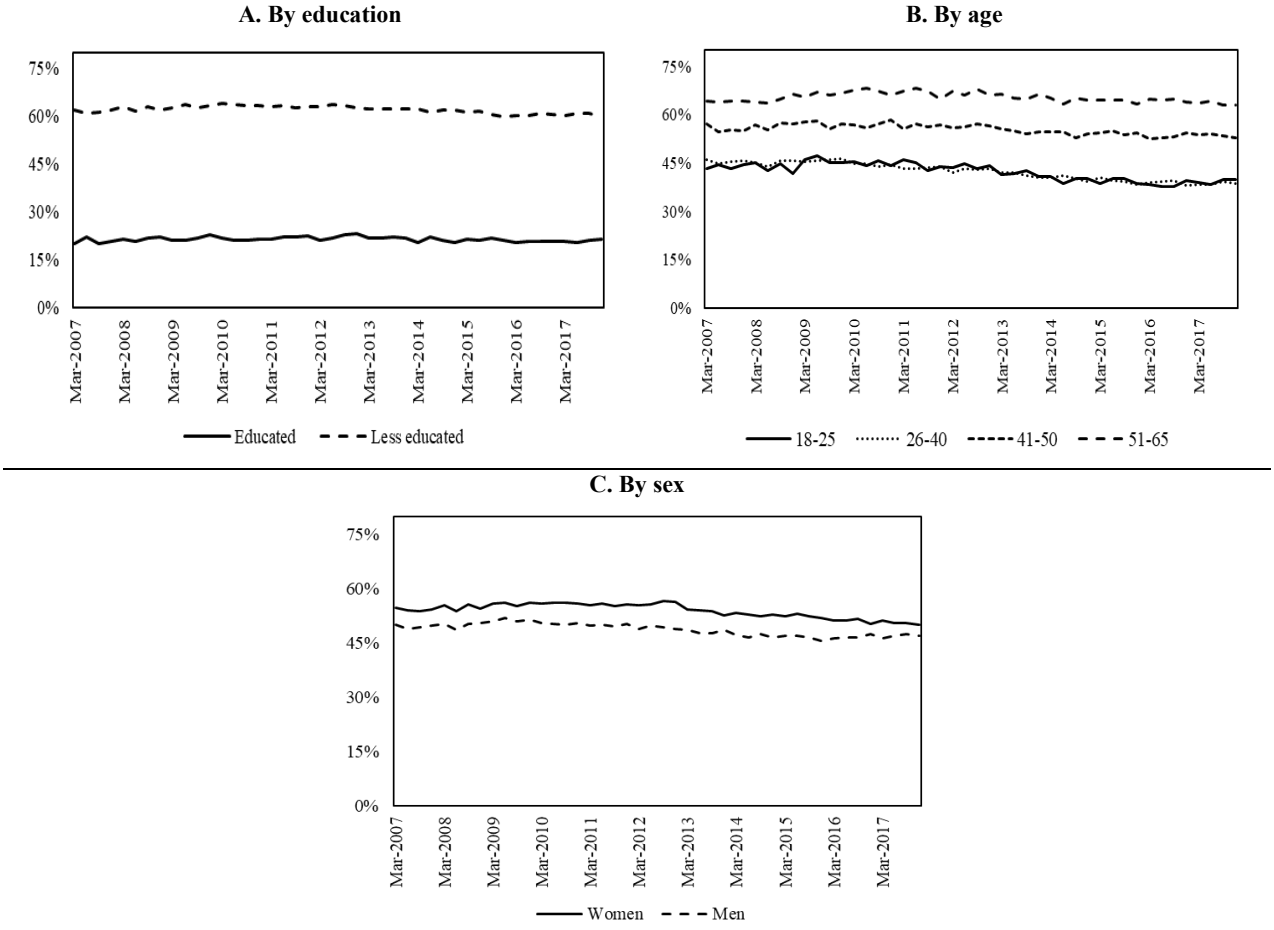
Source: DANE; authors' calculations.

Moreover, since we want to study the level of restrictiveness of the MW in different demographic groups in the Colombian labour market, we split the workers of each city into sixteen groups. These are obtained dividing population by sex, age (18 to 25, 26 to 40, 41 to 50 and 51 to 65 years old) and two levels of education (more-educated and less-educated). Workers classified as more educated are those "with at least 12 years of schooling" while those classified as less educated correspond to workers "with 11 years of schooling at most". Figure 2 shows informality rates by groups corresponding to 23 cities. Panel A of the figure shows the rates of more-educated and less-educated workers. Labour informality of more-educated workers was, on average, 20.8 percent in 2017 while for less-educated workers, it was 60.4 percent. Panel B of Figure 2 shows the informality rate by age of workers. In 2017, the highest levels of informality correspond to the oldest; in fact, workers with age between 51 and 65 years old exhibit a 63.4 percent of informality rate while those aged between 41 and 50-years old reports a 53.5 percent rate, on average. Panel C shows the informality rate by gender. During the sample period, the average rate corresponding to women was higher that men's by more than five pp.

The hypothesis that there is a correlation between the MW and labour informality in Colombia is far from new (see, for example, Maloney, 2004). However, the evidence of a relationship between these two variables in Colombia is rather limited. Mora & Muro (2017), using a dynamic pseudo panel approach, find that an increase in the MW result in an increase in informality. Arango & Flórez (2021) also find a positive effect of MW on the level of informality using a panel data approach of 23 main cities. This approach exploits the variation of the MW ratio defined above across cities. The authors show that an

increase of one pp of MW ratio increases the informality rate on 0.143 pp on average. These authors also find an important heterogeneity effect among the 23 main cities. For example, the effect of the MW is higher in cities such as Ibagué, Neiva, Florencia, and Quibdó than in some others.

Figure 2. Labour informality rate by demographic groups



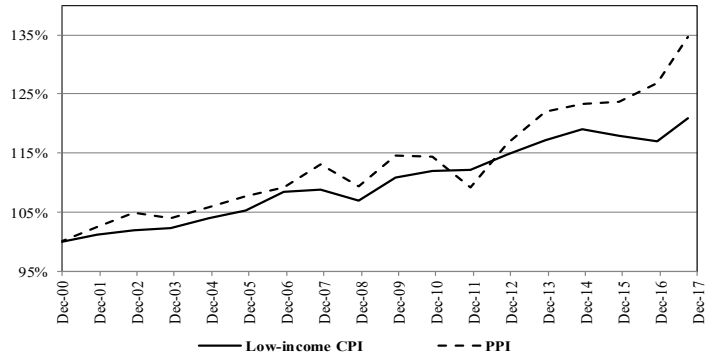
Source: DANE; authors' calculations

Figure 3 shows the behaviour of the MW during the past two decades. Deflated with either the PPI or CPI for low-income people, the MW exhibits a positive and steep trend. On average, between 2000 and 2017, it increased yearly about 1.1 percent when it is deflated with the CPI or 1.8 percent when it is deflated with the PPI. These numbers should imply an important increase in labour productivity of less-skilled workers; nevertheless, given the high labour informality rate, the evidence does not seem support this conjecture.

The definition of the number of labour market groups is a crucial aspect of this methodology since it implies a trade-off between having a large number of cells (of each group) with few individuals per cell (group) and a smaller number of cells with more individuals. A representative sample of each group is required to produce precise estimates of the MW ratio. Also, they should have homogeneous individuals within each cell, to minimize the measurement error when calculating the average MW's stringency

across groups; but the number of groups should also introduce sufficient heterogeneity to allow enough variation between cells to obtain more precise estimates of the parameter of interest. Thus, we end up with 16 groups which are the combination of three sex, four group of age and two types of education (more and less educated) and disregard all possible cell sizes lower than 50 individuals.[10]

Figure 3. Real minimum wage



Source: Ministry of labour; DANE; authors' calculations

Initially, as a measure of MW strictness, we calculated the ratio of MW to the 70th percentile of wages for each of the 16 groups (MR ratio). The wage measure corresponds to the basic salary; that is, without including additional benefits such as payments for holidays, bonuses, payments in kind, among others. The odd Columns in Table 1 present data for the period 2007-2012 while the even columns display information for the period 2013-2017. The sample has been divided to observe possible changes following the implementation of the 2012 tax reform (see Figure 1). The first two columns present the composition of all workers (23 cities) by different demographic characteristics. In general, we can observe that, for the two periods, the higher proportion of occupied workers corresponds to less-educated men (15.81 percent) and women (11.87 percent) between 26 and 40 years old. Moreover, the proportions of more-educated occupied women are slightly higher than the proportion of more-educated occupied men at all ages.

Columns (3) and (4) of Table 1, present the probability of being informal worker for each group. As we can observe there is a higher probability of being informal among less-educated workers, with a higher probability in the case of women. For example, in the last period, less-educated women between 51 and 65 years old have 82.39 percent probability of being informal, while for the case of men in the same group of education and age, this probability is around 70 percent. Furthermore, both educated, and less-educated men have a lower probability of being informal across all groups compared to women.

[10] Verbeek & Nijman, 1992, 1993) recommend that to eliminate any possible bias the data should disregard all possible cell sizes lower than 100 individuals. However, given the robustness exercises we present 50 individuals per cell seem enough.

Table 1 also presents the value of the MW ratio for the two sub-periods. In any case, both ratios are higher for women than for men, and even more so for those with less education.

Table 1. Composition and probability of being informal

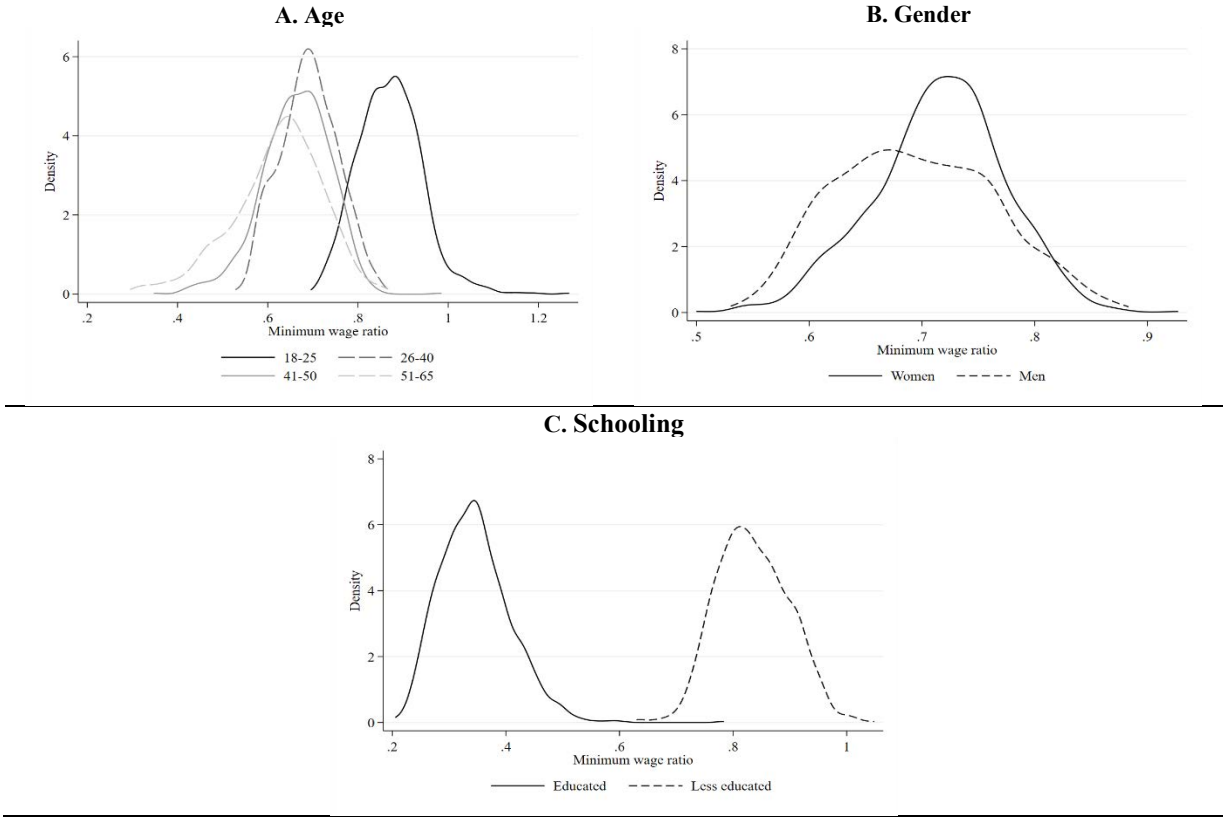
Group	Composition of occupied workers		Probability of being informal		MW ratio: average	
	2007-2012	2013-2017	2007-2012	2013-2017	2007-2012	2013-2017
Age	**(1)**	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**
			Educated women			
18-25 years old	1.80%	2.46%	20.43%	19.75%	0.56	0.63
26-40	6.51%	7.90%	19.88%	19.66%	0.33	0.37
41-50	2.94%	2.95%	24.90%	25.29%	0.23	0.26
51-65	1.49%	1.96%	27.67%	29.98%	0.18	0.20
			Less educated women			
18-25	5.78%	5.15%	53.60%	49.70%	0.89	0.89
26-40	11.87%	10.42%	63.11%	59.50%	0.86	0.88
41-50	7.82%	6.87%	73.53%	71.64%	0.85	0.89
51-65	5.27%	6.27%	83.29%	82.39%	0.79	0.85
			Educated men			
18-25 years old	1.26%	1.78%	17.69%	17.19%	0.54	0.60
26-40	5.69%	6.65%	17.58%	16.08%	0.29	0.33
41-50	2.85%	2.72%	23.06%	22.48%	0.19	0.23
51-65	1.97%	2.30%	26.81%	25.74%	0.15	0.18
			Less educated men			
18-25	8.15%	7.56%	47.32%	44.78%	0.88	0.86
26-40	15.81%	14.22%	50.39%	47.40%	0.76	0.77
41-50	9.10%	7.98%	62.72%	60.10%	0.72	0.75
51-65	6.95%	7.82%	72.61%	70.08%	0.69	0.73

Source: DANE; authors' calculations.

Figure 4 presents the kernel distribution of the MW ratio across groups. Panel A shows the kernel density by age groups where, as expected, for young workers (18-25 years old) the MW is more binding compared to the older workers. Panel B presents the kernel distribution by gender where, apart from the higher skewness of the women's, the level of bindingness of the MW ratio of women seems higher than that of men. In other words, the MW ratio is higher for women than for men. Finally, panel C presents the differences across levels of education. In this case, the MW ratio is far more restrictive for the case of the less-educated workers.

Arango *et al*. (2022, Introduction) explains the variables considered each year in the bargaining process to increase the MW. Thus, both the MW and the real wage in the vicinity of the 70th percentile are both potentially endogenous. Moreover, since the determinants of both are not orthogonal, in Table A1 from Appendix A, we provide evidence of the association between the two variables (see also Arango *et al*., 2022, section 1). In consequence, the null correlation between the MW and the 70th percentiles cannot be taken for granted; thus, we modify the model to have this fact into account, as we will explain below.

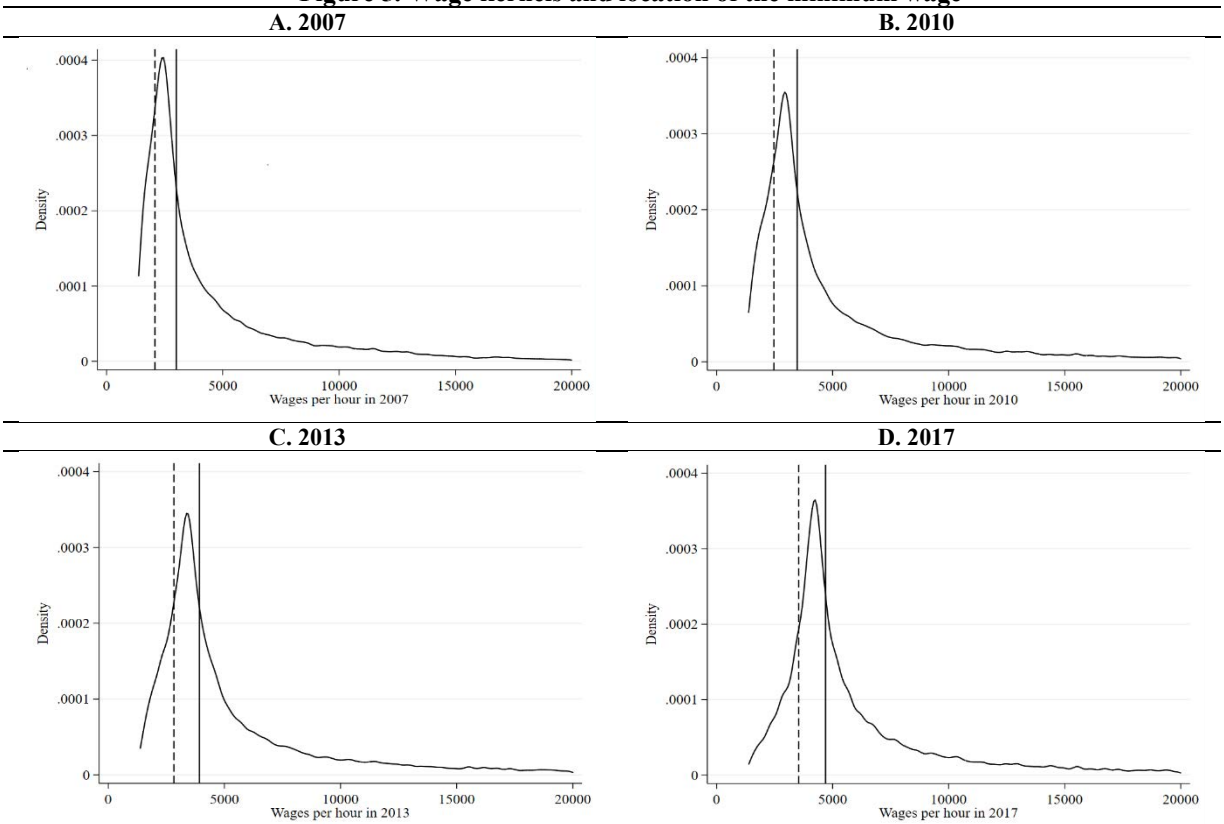
Figure 4. Kernel distribution of the minimum wage ratio by demographic groups



Note: Kernel density estimation of the deviation of MW ratios by group of each city with respect to the average of 23 cities. Kernel density distribution by group was estimated on the averages of the MW ratios of each city in each quarter. Source: DANE; authors' calculations.

Figure 5 shows the kernel distributions of real hourly wage of salaried workers for 2007, 2010, 2013 and 2017. There are some facts worth noticing here. In first place, during these years both the minimum and the median wage increased (both moved to the right). This coincidence of movements casts some doubts on the assumption that the wage distribution is not affected by the MW (see Arango et al., 2022, section 1). Second, while the tails of the kernels exhibit some leptokurtosis, the positive skewness of the distributions have been reducing slowly over the years. As a result, the density looks more well-behaved in 2017 than in 2007. We shall use this fact to refine the identifying assumption of the approach we follow below.

Figure 5. Wage kernels and location of the minimum wage



Note: the vertical continuous line represents the median wage while the vertical dashed line is the MW. Source: DANE; authors' calculations.

4. Empirical approach

4.1 The effect of the MW on the probability of having an informal job

As we mentioned above, we want to estimate the probability of each individual to be informal, controlling by the group that the worker belongs to. This empirical approach, corresponds –in general– to the two-sectors: covered and not covered (Welch, 1974), where, as explained above, the ratio of MW to the 70th percentile of salaried workers of each group is used as a measure of the MW strictness.[11] However, to tackle any endogeneity of the MW ratio, in first place, we start the analysis by lagging it one period. Thus, the linear model estimated at the individual level is given by

$$y_{ijct} = c + \alpha MWR^{0}_{jct-1} + \beta_i Z_i + \delta_i X_i + \mu_c + \mu_t + \varepsilon_{it} \qquad (1)$$

[11] Arango & Flórez (2021) use a demand-supply framework to find the determinants of labour informality. Apart from the MWR, non-wage labour costs, interest rate, business cycle indicator, and other mechanisms in which preferences of individuals' and some other technological aspects of each city play a role.

where y_{ijct} is the outcome variable that takes the value of 1 if the individual i belonging to group j of city c in time t is classified as an informal worker. MWR^0_{jct-1}, $MW_{t-1}/W_{jct-1}(70)$ corresponds the lag of the MW ratio of group j in city c. Z_i are dummy variables that identify the gender, education and age of the individual; X_i is a set of variables that includes some individual's characteristics such as whether the individual is the head of the household or not, the size of the individual household and the economic sector where the individual works;[12] μ_c and μ_t are city and time fixed effects, respectively. Finally, ε_{it} corresponds to the error process. The parameter of interest, α, captures the average effect of the lagged MWR^0_{jct} of the labour market group on the probability of having an informal occupation. As stated before, our empirical strategy exploits the variation of the difference level of strictness of the MW among different demographic labour market groups. Hence, those groups may respond in a different way to the MW policy and, as a result, the impact on labour informality levels may be higher in labour market groups whose wage is closer to the MW.

It is important to observe that we use the lagged value of the MW ratio to mitigate any endogeneity of the MW ratio that could bias the estimation of the parameter α due to an omitted contemporaneous unobservable variable.[13] However, the endogeneity problem may still be present.[14] To overcome this problem, we introduce two exogenous measures of the MW ratio; the first one is the "surprise of the MW ratio" defined as $MWSR^1_{jct} = MW\ surprise/W_{jct-1}(70)$. The *MW surprise* corresponds to the difference between the observed annual increase of the monthly MW and the expected increase of the monthly MW based on the excess increase of the MW over the underlying fundamentals: inflation and productivity (for details see Arango *et al*., 2022, p.47). The denominator corresponds to the lagged value of the observed wage at the 70th percentile of the wage distribution, $W_{jct-1}(70)$, for each demographic group. Then using the "surprise of the MW ratio", MWR^1_{jct}, we estimate the following equation:

$$y_{ijct} = c + \alpha MWSR^1_{jct} + \beta_i Z_i + \delta_i X_i + \mu_c + \mu_t + \varepsilon_{it} \qquad (2)$$

where, as before, y_{ijct} is the outcome variable that takes the value of 1 if the individual i belonging to group j of city c in time t is classified as an informal worker. $MWSR^1_{jct}$ corresponds the *surprise MW ratio* of group j in city c. The parameter of interest, α, captures the average effect of the *surprise MW ratio* of the labour market group on the probability of having an informal occupation.

[12] We have seventeen sectors according to ISIC Rev3 two digits.
[13] Neumark and Wascher (2008, section 3.4.2.) and the references therein- is devoted to the analysis of the inclusion of lagged values of the minimum wage to estimate the effects of this variable on employment.
[14] Appendix A presents evidence on the effects of the MW on the wage distribution of the vicinity of the 70th percentile.

The second exogenous measure of the MW ratio is defined as the $MWSR^2_{jct} = MW\ surprise/\widehat{W_{jct}(70)}$, where the numerator is the same as in $MWSR^1_{jct}$, but the denominator is estimated following Author, Manning, and Smith (2016). That is,

$$W_{jct}(70) = \gamma_c + \gamma_{jct} \times time_t + \gamma_t + \varepsilon_{jt} \qquad (3)$$

where $W_{jct}(70)$ is the 70th percentile of wages for the group j in city c in time t; γ_c is a city effect, γ_{jct} corresponds to a trend that reflects the trajectory of the productivity of the workers in group j, city c and time t; γ_t are common time effects, and ε_{jt} corresponds to the error process. Once we have the estimation of the wage at the 70th percentile of the wage distribution, $\widehat{W_{jct}(70)}$, we calculate $MWSR^2_{jct}$ and use it as our second measure of exogenous MW ratio and estimated the following equation:

$$y_{ijct} = c + \alpha MWSR^2_{jct} + \beta_i Z_i + \delta_i X_i + \mu_c + \mu_t + \varepsilon_{it} \qquad (4)$$

As before, where y_{ijct} is the outcome variable that takes the value of 1 if the individual i belonging to group j of city c in time t is classified as an informal worker. $MWSR^2_{jct}$ corresponds the second measure of the *surprise MW ratio* of group j in city c. Table 2 present the results from estimating equation (2), (3) and (4), using traditional MW ratio and the two *surprise MW ratios*.

Table 2 shows the marginal effects derived from the OLS model specified in equation (1) to estimate the probability that a worker has an informal occupation. In all specifications the standard errors are clustered at group level to avoid overstating the precision of the estimates (see Colin Cameron & Miller, 2015). Columns (1) and (2) show the estimates of the model that uses the lagged MW ratio with the two definitions of informality: firm's size and the lack of social security affiliation. The lagged MW ratio coefficients are significant and suggest that an increase of one percentage point (pp) in the ratio increases the probability of being informal by 0.1596 pp with the firm's size definition and 0.0725 pp with the lack of social security affiliation one.

As is expected, women exhibit a higher probability of being informal with respect to men, with a similar pattern observed among less educated workers with respect to the more educated. Interestingly, the probability of becoming informal increases steadily with age, showing significant differences across each group compared to the reference group (26 to 40 years old). Thus, younger workers have a lower probability of being informally employed when the firm's size definition of informality is considered (-0.0693pp) while under the definition of the lack social security affiliation the coefficient is positive (0.0284pp). In contrast, workers aged 41 to 50 and 51 to 65, are more likely to be informal compared to workers from 26 to 40 years old.

Table 2. Probability of having an informal occupation. Marginal effects (OLS models).

Variables	Equation (1)		Equation (2)		Equation (4)	
	Firm's size	Lack of social security affiliation	Firm's size	Lack of social security affiliation	Firm's size	Lack of social security affiliation
	(1)	(2)	(3)	(4)	(5)	(6)
MWR^0	0.1596***	0.0725				
	(0.0307)	(0.0441)				
$MWSR^1$			0.1069***	0.0390		
			(0.0282)	(0.0313)		
$MWSR^2$					0.0922***	0.0236
					(0.0276)	(0.0324)
Sex (woman)	0.0719***	0.0640***	0.0839***	0.0696***	0.0836***	0.0688***
	(0.0135)	(0.0134)	(0.0154)	(0.0154)	(0.0154)	(0.0154)
Less educated (11 or less years of education)	0.1583***	0.1842***	0.2277***	0.2165***	0.2296***	0.2179***
	(0.0194)	(0.0326)	(0.0133)	(0.0171)	(0.0132)	(0.0171)
18 to 25 years old (reference group 26 to 40 years old)	-0.0693***	0.0284**	-0.0551***	0.0350**	-0.0552***	0.0348**
	(0.0110)	(0.0119)	(0.0141)	(0.0140)	(0.0142)	(0.0139)
41 to 50 years old	0.1067***	0.0628***	0.1005***	0.0599***	0.1002***	0.0599***
	(0.0076)	(0.0137)	(0.0097)	(0.0144)	(0.0097)	(0.0142)
51 to 65 years old	0.2020***	0.1194***	0.1910***	0.11494***	0.1902***	0.1143***
	(0.0112)	(0.0153)	(0.0128)	(0.0144)	(0.0127)	(0.0142)
Additional individuals' controls	Yes	Yes	Yes	Yes	Yes	Yes
ISE (t)	Yes	Yes	Yes	Yes	Yes	Yes
City, year and quarter controls	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R^2	0.3022	0.2143	0.3018	0.2142	0.3018	0.2147
Observations	2,780,489	2,780,489	2,780,489	2,780,489	2,838,277	2,838,277

Note: The restrictiveness of MW is measured as: the lag of the MWR^0_{jct-1} in Column (1) and Column (2); the surprise rate of MW: $MWSR^1_{jct}$ in Column (3) and (4) and the surprise rate of MW: $MWSR^2_{jct}$ in Columns (5) and (6). The MWR represents the MW per hour relative to the 70th percentile of wages. $MWSR^1_{jct} = MW\ surprise/W_{jct-1}(70)$ and $MWSR^2_{jct} = MW\ surprise/\widehat{W_{jct}(70)}$; where the $MW\ surprise$ is defined as the difference between the observed annual increase of the monthly MW and the expected increase of the monthly MW based on its underlying fundamentals: inflation and productivity. Additional individuals' controls: head of household, size of the household and economic sector. ISE is the Index of Economic Situation common to all cities at time t. *** = Significant at the 99% confidence level, ** = Significant at the 95% confidence level, * = Significant at the 90% confidence level. Standard errors clustered at group level. Source: DANE; authors' calculations.

Columns (3) to (6) show the estimates of the model when we use the two exogenous measures: $MWSR^1_{jct}$ and $MWSR^2_{jct}$. Notice that in this case, the results remain significant only when informality is defined by firm's size. In these cases, we find that an increase of one pp in the surprise MW ratio, the probability of being informal increase by 0.1069pp, column (3), or 0.0922, column (5). Again, women, less educated workers, and older workers are more likely of being informal. The fit of the models with the firm's size definition is higher than the lack of social security affiliation.

4.2 The heterogenous effect of the MW across demographic groups

As we can observe, the specifications in equations (2) and (4) do not allow us to analyse the heterogeneous effects of the ratio on the informality rate. In other words, the coefficients linked to the MW ratios in the regressions of Table 2 corresponds to average effects but does not show any differential influence across demographic groups. Thus, to account for any potential heterogeneity, we take

advantage of the source of variation provided by the different restrictedness of the MW ratio for each of the sixteen demographic groups, which is the support of our identification strategy. To accomplish this task, each of sixteen groups is interacted with the MW ratios previously defined, such that the empirical models are conditioned as follows:

$$y_{ijct} = c + \alpha_j(G_j \times MWR^0_{jct-1}) + \delta_i X_i + \mu_j + \mu_c + \mu_t + \varepsilon_{it} \quad (5)$$

$$y_{ijct} = c + \alpha_j(G_j \times MWSR^1_{jct}) + \delta_i X_i + \mu_j + \mu_c + \mu_t + \varepsilon_{it} \quad (6)$$

$$y_{ijct} = c + \alpha_j(G_j \times MWSR^2_{jct}) + \delta_i X_i + \mu_j + \mu_c + \mu_t + \varepsilon_{it} \quad (7)$$

Where, in addition to the notation introduced so far, G_i are dummy variables that identify the group at which the individual belongs while μ_j represents group fixed effects. That dummy takes the value of 1 when the MW ratio corresponds to that particular group, otherwise it takes the value of zero. The parameter of interest, α_j, captures the average effect of the MW ratio of each group j, in the probability that worker i, that belongs to such group, has an informal occupation.

Table 3 shows the marginal effects of the models in equations (5) - (7), using the three MW ratios, MWR^0_{jct-1}, $MWSR^1_{jct}$, and $MWSR^2_{jct}$. In first place, an important heterogeneity is observed in the effects of the interaction of the MWR with these three dimensions (age, education, and gender) of the individuals; however, different from what we saw in Table 3, the coefficients of models in Columns (2), (4) and (6), corresponding the measurement of informality as the lack of social security affiliation, are no longer lower as the general case. The coefficients linked to the MW ratios of each group have, in general, different values.

In second place, it is noticeable that the point estimates of the coefficients of interest, in Columns (1) and (2), are obtained with highest precision across specifications, consequently the standard errors of estimates are much lower than those of the Columns (3) - (6).[15] Nevertheless, the models in Columns (1) and (2) do not exhibit a higher goodness of fit that those, respectively, in Columns (3) to (6). In addition to this general view of the models, we can observe that the coefficients corresponding to the average effect of the MW ratios on the probability of being an informal worker rank between -0,2542 in Column (1) and -0.9826 in Column (6). In a strict sense, these coefficients correspond to the reference group (educated men with ages between 26 and 40 years old), which implies that for educated men with ages

[15] Presumably, an important contribution to the high standard errors of the estimation is made by the surprise MW.

between 26 and 40 years old, the probability of being informal is negative once we control for the rest of variables in the models.

Table 3. Marginal (OLS) effects of the MR ratios on the probability of having an informal occupation. Equations (5) – (7).

Variables	Equation (5) based on the lag of MWR[0].		Equation (6) based on MWSR[1].		Equation (7) based on MWSR[2].	
	Firm's size	Lack of social security affiliation	Firm's size	Lack of social security affiliation	Firm's size	Lack of social security affiliation
	(1)	(2)	(3)	(4)	(5)	(6)
MWR (reference: educated men between 26 and 40 years old)	-0.2542***	-0.3658***	-0.3092**	-0.6722***	-0.4076*	-0.9826***
	(0.0454)	(0.0522)	(0.1449)	(0.2127)	(0.1961)	(0.2882)
MWR of men 18 to 25 educated	0.1965***	0.2540***	0.1506**	0.2865***	0.1783*	0.4121***
	(0.0216)	(0.0225)	(0.0625)	(0.0940)	(0.0839)	(0.1265)
MWR of men 18 to 25 less educated	0.7155***	0.7130***	0.2892***	0.5204***	0.3443**	0.7173***
	(0.0144)	(0.0284)	(0.0922)	(0.1334)	(0.1266)	(0.1844)
MWR of men 26 to 40 less educated	0.4642***	0.6020***	0.2483**	0.4389***	0.2922**	0.6079***
	(0.0108)	(0.0192)	(0.0847)	(0.1222)	(0.1169)	(0.1698)
MWR of men 41 to 50 educated	-0.1148***	-0.2533***	-0.0533	-0.2514**	-0.1472	-0.4555**
	(0.0089)	(0.0101)	(0.0797)	(0.1140)	(0.1076)	(0.1568)
MWR of men 41 to 50 less educated	0.3013***	0.4629***	0.2252**	0.3931***	0.2668**	0.5564***
	(0.0240)	(0.0282)	(0.0811)	(0.1161)	(0.1119)	(0.1616)
MWR of men 51 to 65 educated	-0.2703***	-0.4905***	-0.0450	-0.5850***	-0.2058	-0.9580***
	(0.0187)	(0.0116)	(0.1200)	(0.1786)	(0.1731)	(0.2555)
MWR of men 51 to 65 less educated	0.2547***	0.4133***	0.2499***	0.4102***	0.3019**	0.5619***
	(0.0321)	(0.0335)	(0.0794)	(0.1136)	(0.1087)	(0.1570)
MWR of women 18 to 25 educated	0.2093***	0.3834***	0.2364***	0.4084***	0.2636***	0.5346***
	(0.0208)	(0.0185)	(0.0603)	(0.0912)	(0.0845)	(0.1265)
MWR of women 18 to 25 less educated	0.5321***	0.5659***	0.3037***	0.5528***	0.3634**	0.7535***
	(0.0187)	(0.0194)	(0.0939)	(0.1344)	(0.1290)	(0.1859)
MWR of women 26 to 40 educated	0.1023***	0.0494***	0.1600***	0.1196***	0.1717***	0.1906***
	(0.0054)	(0.0027)	(0.0143)	(0.0191)	(0.0205)	(0.0277)
MWR of women 26 to 40 less educated	0.3496***	0.5609***	0.2852***	0.5014***	0.3416**	0.7022***
	(0.0206)	(0.0194)	(0.0927)	(0.1315)	(0.1278)	(0.1830)
MWR of women 41 to 50 educated	0.0124	0.0190	0.1217**	-0.0247	0.1006*	-0.1068
	(0.0107)	(0.0174)	(0.0427)	(0.0684)	(0.0559)	(0.0865)
MWR of women 41 to 50 less educated	0.2955***	0.4795***	0.3072***	0.5179***	0.3651**	0.7098***
	(0.0477)	(0.0569)	(0.0919)	(0.1286)	(0.1262)	(0.1787)
MWR of women 51 to 65 educated	0.0639***	-0.0022	-0.0149	-0.3616**	-0.0372	-0.6035**
	(0.0196)	(0.0267)	(0.0950)	(0.1439)	(0.1428)	(0.2148)
MWR of women 51 to 65 less educated	0.3627***	0.5145***	0.3098***	0.4899***	0.3781***	0.6783***
	(0.0562)	(0.0649)	(0.0887)	(0.1229)	(0.1202)	(0.1690)
Group FE	Yes	Yes	Yes	Yes	Yes	Yes
Additional individuals' controls	Yes	Yes	Yes	Yes	Yes	Yes
ISE (t)	Yes	Yes	Yes	Yes	Yes	Yes
City, year and quarter controls	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R^2	0.304	0.217	0.303	0.216	0.303	0.217
Observations	2,780,489	2,780,489	2,780,489	2,780,489	2,838,277	2,838,277

Note: The restrictiveness of MW is measured as: the lag of the MWR^0_{jct-1} in Column (1) and Column (2); the surprise rate of MW: $MWSR^1_{jct}$ in Column (3) and (4) and the surprise rate of MW: $MWSR^2_{jct}$ in Columns (5) and (6). The MWR represents the MW per hour relative to the 70th percentile of wages. $MWSR^1_{jct} = MW\ surprise/W_{jct-1}(70)$ and $MWSR^2_{jct} = MW\ surprise/\widehat{W_{jct}}(70)$; where the $MW\ surprise$ is defined as the difference between the observed annual increase of the monthly MW and the expected increase of the monthly MW based on its underlying fundamentals: inflation and productivity. Additional individuals' controls: head of household, size of the household and economic sector. ISE is the Index of Economic Situation common to all cities at time t. *** = Significant at the 99% confidence level, ** = Significant at the 95% confidence level, * = Significant at the 90% confidence level. Standard errors clustered at group level. Source: DANE; authors' calculations.

The interaction between the MW ratio and the level of education is a key determinant of the results in Table 3. Accordingly, both less educated men and women have a higher probability of having an informal occupation than more-educated men and women within the same range of age. For example, in Column (6), the difference in the coefficients of less and more-educated men between 18 and 25, 0.7173 and 0.4121, is sizeable. Or between women of 26 and 40 years old in Colum (3), where the difference is important as well: 0.1600 and 0.2852.

By the same token, the interaction of the MWR and sex is also fundamental since in all models the point estimates for women are higher than those of men. The exception are the models corresponding to equation (5) in Column (1) for less-educated people of all range ages and in Column (2) for individuals less than 40 years old, where the results are converse. Nevertheless, given the high standard errors, that we mentioned before, it is not possible to assert that all those differences are statistically significant.

Also noticeable is the fact that the coefficients linked to the interaction with the MWR decrease as the age increases. This is the case for both less and more-educated women and men in almost all models. Nevertheless, a reversion in few estimates of people is observed in the cases of less-educated women of 51-65 years old in Columns (1) and (2) and for men of the same age in models of Columns (3) to (6).

Thus, according to the results in Table 3, the MWR affects distinctly most of the groups we have worked with which is one of the aims of the paper. As one would expect from the Figure 1, the coefficients obtained varied depending on the measure of the informality rate: the size of the firm or the lack of social security affiliation.

4.3. Dynamic effects of the MWR.

So far, the evidence of the effect of the MW ratios in the probability of having an informal job seems clear as well as the heterogeneity across demographic groups of such effect. However, it would be arguable that the outcome of the MW in the informality rate last only one period. Thus, in this section, we estimate the dynamic effect of the MW ratio in the probability of having an informal occupation. Accordingly, we use a k-lag polynomial of the different measures of restrictiveness of the MW. In this case, the previous expressions are rewritten as

$$y_{ijct} = c + \sum_{k=1}^{K} \alpha_{jk}(G_j \times MWR^{0}_{jct-k}) + \delta_i X_i + \mu_j + \mu_c + \mu_t + \varepsilon_{it} \quad (8)$$

$$y_{ijct} = c + \sum_{k=1}^{K} \alpha_{jk}(G_j \times MWSR^{1}_{jct-k}) + \delta_i X_i + \mu_j + \mu_c + \mu_t + \varepsilon_{it} \quad (9)$$

$$y_{ijct} = c + \sum_{k=1}^{K} \alpha_{jk}(G_j \times MWSR^{2}_{jct-k}) + \delta_i X_i + \mu_j + \mu_c + \mu_t + \varepsilon_{it} \quad (10)$$

Table 4. Dynamic effects of the MR ratios on the probability of having an informal occupation. Equations (8) to (10).

Variables	Equation (8) based on the lag of MWR^0.		Equation (9) based on $MWSR^1$.		Equation (10) based on $MWSR^2$.	
	Firm's size	Lack of social security affiliation	Firm's size	Lack of social security affiliation	Firm's size	Lack of social security affiliation
	(1)	(2)	(3)	(4)	(5)	(6)
MWR (reference: educated men between 26 and 40 years old)	-0.2751***	-0.4525***	-0.5284***	-1.1488***	-0.3602*	-1.2542***
	(0.0528)	(0.0579)	(0.171)	(0.2048)	(0.1907)	(0.2449)
MWR of men 18 to 25 educated	0.1656***	0.2745***	0.3794***	0.6374***	0.1999***	0.5734***
	(0.0195)	(0.0194)	(0.071)	(0.072)	(0.0701)	(0.0847)
MWR of men 18 to 25 less educated	0.8472***	0.8917***	0.5823***	0.9921***	0.3460**	0.9386***
	(0.0145)	(0.030)	(0.1082)	(0.1243)	(0.1236)	(0.1547)
MWR of men 26 to 40 less educated	0.5346***	0.7422***	0.5211***	0.8957***	0.3212**	0.8472***
	(0.0108)	(0.018)	(0.0991)	(0.1115)	(0.1133)	(0.1400)
MWR of men 41 to 50 educated	-0.2438***	-0.4782***	-0.5301***	-0.7801***	-0.2677**	-0.5861***
	(0.0174)	(0.0191)	(0.1152)	(0.1323)	(0.1155)	(0.1481)
MWR of men 41 to 50 less educated	0.3668***	0.5837***	0.4172***	0.8176***	0.2474**	0.7698***
	(0.025)	(0.0272)	(0.097)	(0.1058)	(0.1086)	(0.1325)
MWR of men 51 to 65 educated	-0.4675***	-0.8811***	-0.1402	-0.7585***	-0.0635	-0.6285**
	(0.042)	(0.0323)	(0.1550)	(0.1997)	(0.1853)	(0.249)
MWR of men 51 to 65 less educated	0.2961***	0.5325***	0.4310***	0.8205***	0.2755**	0.8201***
	(0.034)	(0.0320)	(0.097)	(0.1049)	(0.1058)	(0.128)
MWR of women 18 to 25 educated	0.2086***	0.4180***	0.4645***	0.7716***	0.3041***	0.7722***
	(0.0213)	(0.0155)	(0.0741)	(0.0791)	(0.0778)	(0.097)
MWR of women 18 to 25 less educated	0.7040***	0.7632***	0.5827***	0.9873***	0.3554**	0.9866***
	(0.0305)	(0.0287)	(0.1068)	(0.1213)	(0.1240)	(0.1532)
MWR of women 26 to 40 educated	0.0930***	0.0486***	0.2841***	0.2554***	0.1658***	0.2793***
	(0.006)	(0.0029)	(0.0128)	(0.0145)	(0.0208)	(0.0239)
MWR of women 26 to 40 less educated	0.4219***	0.7228***	0.5287***	0.9708***	0.3178**	0.9424***
	(0.031)	(0.0300)	(0.1084)	(0.1192)	(0.1224)	(0.1499)
MWR of women 41 to 50 educated	-0.0390*	-0.0504	0.1373**	-0.0857	0.0414	-0.1229
	(0.022)	(0.0326)	(0.0689)	(0.0996)	(0.0686)	(0.1001)
MWR of women 41 to 50 less educated	0.3282***	0.6603***	0.5252***	0.9182***	0.3245**	0.9051***
	(0.062)	(0.0821)	(0.1138)	(0.1206)	(0.1209)	(0.1457)
MWR of women 51 to 65 educated	0.0344	-0.0147	0.2696*	0.0815	0.1003	-0.4214*
	(0.027)	(0.0497)	(0.1484)	(0.220)	(0.1582)	(0.2264)
MWR of women 51 to 65 less educated	0.4585***	0.7220***	0.5604***	0.8979***	0.3733***	0.9298***
	(0.0721)	(0.085)	(0.1131)	(0.1179)	(0.1157)	(0.1361)
Group FE	Yes	Yes	Yes	Yes	Yes	Yes
Additional individuals' controls	Yes	Yes	Yes	Yes	Yes	Yes
ISE (t)	Yes	Yes	Yes	Yes	Yes	Yes
City, year and quarter controls	Yes	Yes	Yes	Yes	Yes	Yes
Adjusted R^2	0.304	0.217	0.303	0.216	0.303	0.216
Observations	2,595,017	2,595,017	2,536,428	2,536,428	2,595,017	2,595,017

Note: The restrictiveness of MW is measure as: the lag of the MWR in column (1) and column (2); the surprise rate of MW: $MWSR^1_{jct}$ in column (3) and (4) and the surprise rate of MW: $MWSR^2_{jct}$ in column (5) and (6). The MWR represents the MW per hour relative to the 70th percentile of wages. $MWSR^1_{jct} = (MW\ surprise/W_{jct-1}(70))$ and $MWSR^2_{jct} = (MW\ surprise/\widehat{W_{jct}(70)})$; where the $MW\ surprise$ is defined as the difference between the observed annual increase of the monthly MW and the expected increase of the monthly MW based on its underlying fundamentals: inflation and productivity. Additional individuals' controls: head of household, size of the household and economic sector. ISE is the Index of Economic Situation common to all cities at time t. The coefficients and the standard deviations were calculated using the Deltha method from four lags of each variable. * = Significant at the 99% confidence level, ** = Significant at the 95% confidence level, * = Significant at the 90% confidence level. Standard errors clustered at group level. Source: DANE; authors' calculations.**

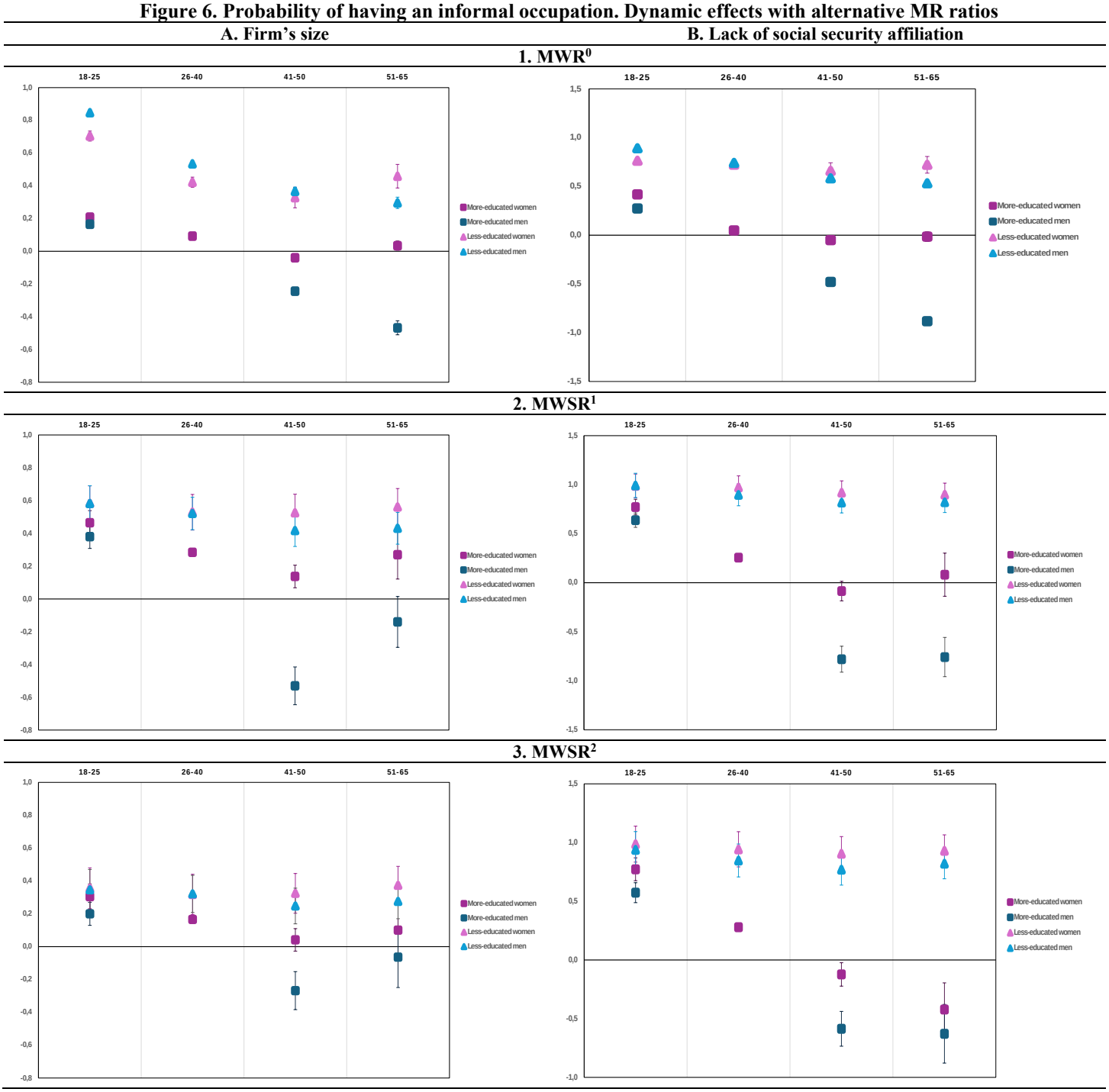
In specifications (8) to (10), the parameters of interest, α_{jk}, capture the complete effect of the strictness of the labour market group's MW to which the individual belongs in the probability of having an informal job. In the estimations of such specifications, we use, respectively, four lags of each of the three MWR; the accumulated four-lag coefficients are presented in Table 4 where we can observe that, in an overwhelming majority, the null hypothesis that $H_0: \sum_{k=1}^{K} \alpha_{jk} = 0$ rejected.

If we focus on Columns (1) and (2), the results show that both younger less-educated male and female workers are the most affected with the MW policy. For example, in the case of youngest men (women) a one pp increase in the MW ratio leads to a 0.8472pp (0.7040pp) increase in their probability of having an informal occupation after four quarters based on firm's size and a 0.8917pp (0.7632pp) increase when considering the lack of social security affiliation. The results when using more exogenous indicators of restrictiveness of the MW such as $MWSR_{jct}^{1}$ and $MWSR_{jct}^{2}$ are qualitatively similar with respect to less-educated workers but older women are particularly affected, even more than men aged 41 and older.

The information of Table 4 can also be observed, and may be more easily, in the format of Figure 6 which shows how the accumulated dynamic effect declines monotonically with the age, especially when using the informality measured by the firm's size. The horizontal axis shows the rank-age of the groups. Here we remark some findings. First, the coefficients within each panel of the figure make it evident the heterogeneity of the effects of the MW among demographic groups; also, when we compare panels of Columns A and B. In general, the youngest and less educated individuals are the most affected by the MW policy, according to our measures, although in some cases the oldest also have high coefficients as we observe in panels 2 and 3, Column A. Second, the descriptive statistics on panel B of Figure 2 and Table 2 suggest some caution; this is because the econometric analysis of Tables 3 and 4 show different findings. In Figure 2 (panel B), we show that the prevalence of labour informality rate is higher for older people as well as in Table 2 where we show that the probability of having an informal job is higher for this same population group. However, once we control for sex and education, within the interaction, the results are different and the most affected are the youngest workers mainly with the MWR^{0}.

The general results show important effects of the MW on the probability that workers have an informal job. This is not the only unique explanation behind the labour informality in Colombia; however, it seems to be an important factor. Thus, the situation of the youngest workers without higher education should be considered when setting the MW increase.

Figure 6. Probability of having an informal occupation. Dynamic effects with alternative MR ratios



Note: The horizontal axis shows the rank-age of the groups. The coefficients and the standard deviations were calculated using the Deltha method from four lags of each variable. DANE; authors' calculations. Source: DANE; authors' calculations.

5. Conclusions and policy implications

Colombia has a long tradition of high and persistent labour informality. Among the main factors behind such outcome are, on the one hand, the disparity between the MW and the labour productivity of less-skilled workers and, on the other hand, the high Kaitz ratio, a number surrounding between 85% and

90%. In this paper, instead of the MW compared to the labour productivity of workers or the Kaitz ratio, we use MW with respect to the 70th percentile of the wage distribution of salaried workers. The main reason for using such ratio is the lack of minimum wage heterogeneity across workers, cities or firms.

With the aim of observing the heterogenous effect of the MW ratio in different demographic groups, an analysis not undertaken before in Colombia, we split the population into sixteen groups by interacting gender (male and female) with four level of ages (18 to 25, 26 to 40, 41 to 50 and 51 to 65 years old) and two levels of education (educated and less-educated workers) for each city. For each group we compute a MW ratio in any period. Then we focus on the effect of the MW ratio on the probability of having an informal job for an individual who belongs to any demographic group. We use two measures of labour informality: the size of the firm [a job is regarded as informal when it corresponds to a firm with a maximum of five employees (comprising all plants), including the employer] and no-affiliation to the social security (pension or health systems).

The identification strategy exploits the variation of the strictness of the MW ratio among different demographic labour market groups. Our hypothesis is that the higher the MW ratio of any group, the higher the probability of having an informal job. For mitigating any potential endogeneity of the MW ratio[16], we lag this variable in the specification, MWR^0_{t-1}, [see equation (1)]. The results show differential effects of the MW ratio on that probability, depending on the group. Given any remaining endogeneity of the MW ratio, we also use two more specifications of it: $MWSR^1_{jct} = MW\ surprise/W_{jct-1}(70)$ and $MWSR^2_{jct} = MW\ surprise/\widehat{W_{jct}(70)}$, where the $MW\ surprise$ is the MW annual increase in excess of the past inflation and productivity, $W_{jct-1}(70)$ is the wage corresponding to the 70th percentile lagged one period, and $\widehat{W_{jct}(70)}$ is computed as in Autor, Manning, & Smith (2016) [see equation (3)].

The results suggest that the level of restrictedness of the MW ratio has a positive effect on the probability of having an informal job, and this effect is heterogeneous across all demographic groups. We find a significant contemporaneous impact on younger, less educated women and men compared to more educated men aged between 26 and 40. For example, using the most exogenous measure $MWSR^2_{jct}$, and by looking at the Columns (5) and (6) at Table 4, an increase of one pp in the MWR for the group of less educated men (women) aged 18 to 25 increases the probability of having an informal job by 0.3443pp (0.3634pp) under the firm's size definition of informality and by 0.7173pp (0.7535pp) in the case of lacking social security affiliation. The magnitude of these effects is monotonically

[16] Of which there is evidence in Arango *et al*. (2022).

decreasing with age up to the fifties when the probability increases for both genders, but specially for less educated women.

We also explore the dynamic effects of the MW; the results are very similar to those contemporaneous but with higher magnitudes since we are accumulating the effects for the whole year. The accumulated probability of being informal decrease with age until the 50ths, when the probability of being informal increase for women and men between 51-65 years old compared to more educated men with 26-40 years old. This result is clearer when we employ MWR^0. With the other two measures of the MWR, older people continue to be affected by the MW but mainly less educated women [see panels 2 and 3 in Figure (6)]. In any case, the education is a key factor behind the probability of being informal, especially for those young and elder workers.

These results suggest at least two lines of careful analysis and policy design. First, increasing the productivity of the population, especially of less-skilled workers, through effective education and job training policies. Second, the way the minimum wage has been managed in recent decades. Its persistent increase has contributed to increase the likelihood of unskilled workers and young people have jobs in the informal sector. Implementing a minimum wage policy focused on young workers with less education and women aged 51 to 65 could be useful.

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Appendix A. Potential endogeneity of the MW ratio

To provide further empirical evidence that the MW affects the wage distribution in the vicinity of the 70th percentile, we run a fixed-effects panel given by $w_{c,t}^{70th} = \delta + \alpha MW_{c,t} + \beta U_{c,t} + \varepsilon_{c,t}$, where $w_{c,t}^{70th}$ is the annual variation of the wage at the 70th percentile in city c in period t, $MW_{c,t}$ the annual variation of the real MW in city c in period t, $U_{c,t}$ the unemployment rate in city c in period t, and, finally $\varepsilon_{c,t}$ is the error term. The unemployment rate of city c is included in the specification to control for some other cyclical variation [see Blanchflower y Oswald (1994)] that might affect the variation in the $w_{c,t}^{70th}$. The estimates of different specifications of the model are shown in Table A1. Column (1) shows that increases of the MW correspond to increases of the wage at 70th percentile. Results in column (2) provide evidence that the MW variation affect the variation of the wage at 70th percentile. Moreover, when the lag of the annual variation of the MW is included into the model, the variation of the 70th percentile also responds to that variable. This result holds even when a lag of the local unemployment rate is included in the specification.

Table A1. Changes of minimum wage and changes of the wage at the 70th percentile of the distribution

Variables	Annual variation of wage at 70th percentile	Annual variation of wage at 70th percentile	Annual variation of wage at 70th percentile
	(1)	(2)	(3)
Annual variation of the hourly MW (t)	0.4197***	-0.1754	-0.1748
	(0.1472)	(0.2381)	(0.2383)
Annual variation of the hourly MW (t-1)		0.7623***	0.7642***
		(0.2443)	(0.2448)
Annual variation of the unemployment rate (t)	0.0360	0.0782	0.0992
	(0.1980)	(0.1511)	(0.1996)
Annual variation of the unemployment rate (t-1)	-0.0599		-0.0312
	(0.1918)		(0.1937)
Constant	0.1668	-0.0537	-0.0598
	(0.3115)	(0.3123)	(0.3148)
Observations	827	817	817
R^2	0.0101	0.0220	0.0220
Number of cities	23	23	23

Note: standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Source: author's calculations.


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