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# ABSTRACT

# Behind the Lighthouse Effect*

A large body of empirical literature indicates that, contrary to predictions from economic theory, wages in the informal sector increase after any minimum wage hike. This phenomenon was so far explained as a byproduct of a signal conveyed by statutory minimum wages to wage setting in the informal sector, as if workers in the latter had significant bargaining power. A simple matching model shows that the lighthouse effect may be induced by significant sorting and composition effects between the formal and shadow sectors in the aftermath of the increase in the minimum wage. Using data on Brazil, we test this alternative explanation of the lighthouse effect, associated with the endogenous sorting of workers by skill in the formal and informal sectors. We find that sorting accounts for at least one third of the increase in average wages in the informal sector after the minimum wage hike. This contribution of sorting to wage dynamics in the informal sector is also increasing over time.

JEL Classification: J30

Keywords: minimum wage, lighthouse effect, sorting

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# 1 Introduction

Economic theory predicts that the introduction of a minimum wage in a dual economy (with a significant portion of the workforce employed in the informal sector) should depress wages in the labor market segment in which the regulation is not enforced. However, much empirical literature, notably on Latin American countries, indicates that wages actually increase in the informal sector after a minimum wage hike. The literature explains this fact in terms of a signal given to wage setting in the informal sector, a *lighthouse* effect, inducing workers in the informal sector to ask for higher wages. This explanation requires that workers in the informal sector do retain substantial bargaining power, something that is lacking empirical support and we find rather unconvincing.

In this paper we provide an alternative rationale for the lighthouse effect on the basis of the shadow sorting model provided by Boeri and Garibaldi (2005), where workers and firms self-select themselves into a formal and an informal sectors. The baseline equilibrium implies a separation of the two labor market segments by skills: low-skilled workers operate in the informal sector and high skilled workers in the formal sector, an implication which is well supported by the data on a variety of countries, including Brazil. The model implies also that the introduction of the minimum wage induces a change in the skill composition of the workforce in the two sectors, and in particular a shift of relatively skilled workers into the informal sector as well as a shift of very low skilled workers in the formal sector. These composition effects induce an increase in the average productivity and average wage in the informal sector. Beyond these labor supply effects, the introduction of the minimum wage has also a standard wage cost effect that tends to reduce employment in the formal sector. Novertheless, our qualitative analysis shows that an increase in the minimum wage in the informal sector, related to a composition effect, is present also in the general equilibrium.

We test our alternative explanation by drawing on data from Brazil, allowing to track workers and wages across the shadow margins. We find support for both, the substantive assumptions of the model (the fact that unskilled workers are concentrated in the informal sector) and its implications (the fact that a minimum wage hike increases the average skill content in the informal sector). We also decompose the total variation in the average wage of the informal sector between the period immediately before and after the change in the minimum wage finding that the "sorting" effect may account for at least one third of the increase in average wages in the informal sector after the minimum wage hike. Moreover, this contribution of sorting is increasing over time.

The paper proceeds as follows. Section 2 reviews the literature on the lighthouse effect, presents the Brazilian data and provides some evidence on the effects of minimum wage hikes on wages in the informal sector. Section 3 presents the baseline shadow sorting model and extends it to accommodate a minimum wage. It then analyses the mechanics behind the lighthouse effect, obtaining a set of propositions that can be taken to the data. Section 4 then goes back to the data and evaluates these empirical implications. Finally, Section 5 briefly summarizes and concludes.

# 2 The "Lighthouse Effect"

## 2.1 Literature review

A standard case considered by economic theory in which a minimum wage does not have a negative effect on employment is a *dual labor market* where the minimum wage does not apply to the secondary or informal labor market. As pointed out by Welch (1976), Gramlich (1976) and Mincer (1976), following a minimum wage hike, workers displaced in the formal sector move to the uncovered sector. Hence, as depicted in Figure 1, wages in the informal sector fall (from $w_o^I$ to $w_1^I$) and labor supply in the formal sector declines (shifting the $L^s$ curve to the left). The minimum wage then reallocates jobs from the formal to the informal sector, increasing the difference between formal and informal wages. This adjustment mechanism prevents fully employment losses only if there is perfect labor mobility between the two sectors and wages are perfectly flexible in the informal sector. Insofar as workers losing their job have no access or limited access to unemployment benefits (Gindling and Terrell, 2004; Maloney and Nunez, 2003), this assumption seems to be acceptable in a relatively large number of developing countries.

Contrary to this theoretical prediction, studies on developing countries (Lemos, 2004, and Fajnzylber, 2001, for Brazil; Gindling and Terrell 2004b for Costa Rica; Jones, 1997, for Ghana) where the informal sector is particularly large quite surprisingly observed instead an *increase* in wages also in the informal sector after a minimum wage hike. Nothwistanding measurement problems, this effect seems rather robust to alternative specifications of the wage equation in the two sectors (Amadeo, Gill, and Neri, 2000, Maloney and Nunez, 2003; Neri, Gonzaga and Camargo, 2000), notably in Brazil where data on the informal sector are considered to be more reliable.

The interpretation provided by this literature is that the minimum wage set in the formal sector is a sort of reference price, a signal for bargaining, throughout the economy at large. If firms

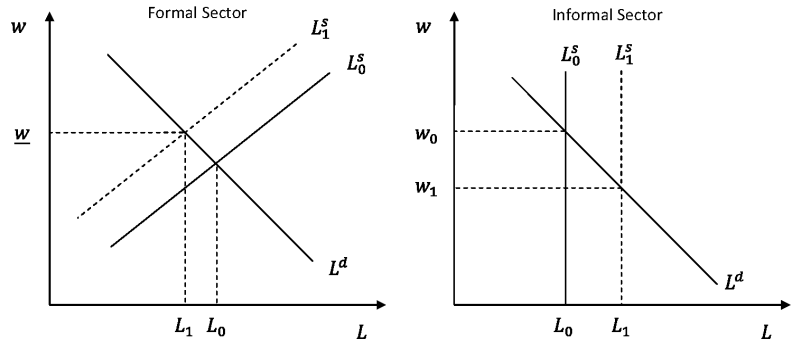


Figure 1: The standard theoretical prediction

have monopsonistic power also in the informal sector, and "fair remuneration" considerations are relevant, it is possible that changes in the minimum wage in the formal (and covered) sector lead to corresponding increases in the average wage of the informal sector. The term "*Efeito Farol*" or "*lighthouse effect*" (Souza and Baltar, 1980) has been used to denote this phenomenon.

No doubt, in countries such as Brazil, the minimum wage provides a reference in the definition of many public sector (including local administrations) wages and some cash transfers and it is also used within collective bargaining in the private sector. It is indeed very common for workers to have their wages defined as multiples of the minimum wage (Amadeo et. al 2000; Camargo,1984, Neri, 1997). However, it is doubtful that in presence of significant flows of workers from the formal to the informal sector, this positive social reference effect on wages could prevail over the negative labor supply shock effect, induced by the presence of a downward sloping labor demand.

Alternative interpretations have called into play substitution effects. Employers could react to a minimum wage hike, by substituting formal workers for informal ones, and the stronger demand for informal workers could more than offset the increase of labor supply in this sector, inducing an increase in the informal sector wages (Fajnzylber 2001).

Other scholars have challenged the idea that the informal sector offers lower quality jobs than the formal sector (Maloney, 1999). Under such conditions, an increase in the minimum wage may make the formal sector a more attractive destination to some informal workers and actually induce a decrease in the supply of labor in the informal sector, resulting in an increase in informal sector wages.

Although the empirical literature on minimum wages in developing countries is still rather

young, due to a paucity of data, there is some literature on the lighthouse effect also for other Latin American countries. Maloney and Nunez (2003) found evidence of the lighthouse effect in Mexico, Argentina, Uruguay, Brazil, Chile, Honduras and Colombia. They actually concluded that in these countries the influence of the minimum wage appears to be more significant in the informal sector than in the formal sector. Gindling and Terrell (2004), however, do not find evidence of the lighthouse effect in Costa Rica.

## 2.2 Definitions and data

The consensus definition of the shadow economy is "all economic activities which contribute to the officially calculated (or observed) gross national product, but escape detection in the official estimates of GDP" (Feige, 1989 and 1994; Lubell, 1991 and Schneider 1994). This definition encompasses not only legal, but also illegal activities, such as trade in stolen goods, drug dealing, gambling, smuggling, etc.. In this paper we confine our attention to a subset of the shadow economy, namely to legal activities. Our notion of shadow employment is one of a lawful activity were it reported to tax authorities and subject to work regulations, as our aim is to contribute to the literature on the enforcement of labor regulations and to complement research on tax evasion, which has so far overlooked the effects of tax evasion and shadow employment on unemployment[1].

The data set we use for our analysis is the Pesquisa Mensal de Emprego (PME), a longitudinal survey performed by the Brazilian statistical agency (IBGE) since 1980. PME is a monthly employment survey of households in 6 of the major Brazilian metropolitan regions, namely Bahia, Pernambuco, Rio de Janeiro, Minas Gerais, São Paulo and Rio Grande do Sul. It is organized as a rotating panel, interviewing each of the households for four consecutive months, not interviewing them for the next eight months and then interviewing them again for four months before they are definitely excluded from the sample, as summarized by Table 1.

[1] See Burdett, Lagos and Wright (2000) for an analysis of the relationship between crime and unemployment.

**Table 1. The rotation scheme of the PME**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | $\underbrace{P1, P2, P3, P4}$ | $\underbrace{P1, P2, P3, Q4}$ | $\underbrace{P1, P2, Q3, Q4}$ | $\underbrace{P1, Q2, Q3, Q4}$ | $\underbrace{Q1, Q2, Q3, Q4}$ | $\underbrace{Q1, Q2, Q3, R4}$ | |
| ***month*** | 1 | 2 | 3 | 4 | 5 | 6 | |
| | $\underbrace{Q1, Q2, R3, R4}$ | $\underbrace{Q1, R2, R3, R4}$ | $\underbrace{R1, R2, R3, R4}$ | $\underbrace{R1, R2, R3, P4}$ | $\underbrace{R1, R2, P3, P4}$ | $\underbrace{R1, P2, P3, P4}$ | $\underbrace{P1, P2, P3, P4}$ |
| | 7 | 8 | 9 | 10 | 11 | 12 | 13 |

Althought the increase of the informality in the Brazilian labor market dates back to the 1980s, it is only in the 1990s that it became really significant, independently of cyclical fluctuations (Amadeo et al., 1994).

According to the Brazilian legislation, all workers must have a signed work card; workers without such a card are considered informal workers since they do not pay taxes and social security contributions. In the PME there is a question that asks the interviewee if she/he has this work card, so that it is possible to disentangle formal from informal sector workers [2]. This distinction, however, does not apply to the civil servants. Hence, in our analysis we decided to focus only on private sector employees.

Table 1 below provides some descriptive statistics on formal vs informal sector employees in the various years covered by our analysis. Informal sector workers in our sample represent roughly one third of the employees. Other studies (Ulyseea (2006)) reach estimates as high as 40 per cent, so that it is quite possible that our data undersample shadow sector workers. Women and young workers are overrepresented in the informal sector compared with the formal sector. Over time, educational attainments are increasing in both sectors, probably as a result of the efforts put by the Brazilian Government to increase the education level of the population. Consistently with evidence on other countries, formal sector employees are, on average, more educated than informal sector ones, a key prediction of the model originally presented by Boeri and Garibaldi (2005) and further discussed below.

[2] Many authors also consider the self-employed as belonging to the informal sector. In our analysis we will focus only on employees.

**Table 2. Descriptive statistics on the two sectors**

| | Total | | Female | | Age (years) | | Education (years) | | Nom. wage (ln, Reais h.) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | *For* | *Inf* | *For* | *Inf* | *For* | *Inf* | *For* | *Inf* | *For* | *Inf* |
| 1995 | 208242 | 86038 | 36.58% | 43.29% | 33.25 | 30.05 | 7.48 | 6.03 | 3.34 | 2.78 |
| | | | (.48) | (.49) | (10.97) | (12.84) | (4.06) | (3.81) | (.88) | (.89) |
| 2000 | 198166 | 97216 | 39.90% | 45.24% | 33.82 | 31.95 | 8.56 | 7.43 | 3.80 | 3.34 |
| | | | (.49) | (.50) | (10.85) | (12.77) | (3.91) | (3.91) | (.81) | (.85) |

## 2.3 Minimum Wage Adjustments, Spikes and the Lighthouse Effect in Brazil

The first minimum wage was introduced in Brazil in 1940. The level was established in each region by a Wage Commission whose main concern was to provide subsistence remuneration of a single adult worker for a normal working day. Since 1984 the minimum wage is set at the national level. The Constitution (approved in 1988) states that the minimum wage should be the same throughout the country and must be sufficient to meet the basic needs of workers and their families, in terms of housing, education, health, recreation, clothing, hygiene, transportation, and social security. The wage is adjusted periodically by the Ministério do Trabalho e Emprego to preserve its purchasing power and there is also a norm prohibiting the use of minimum wage as an indexation parameter for other transfers. Nevertheless, such a norm is rarely enforced.

Our analysis covers the period 1995 to 2000 neglecting the previous years of hyperinflation.Over this period the minimum wage was adjusted annually in May except for the year 2000, when the adjustment occurred in April. In this 6-years period, the level of the real hourly minimum wage experienced a large increase in May 1995 and then declined to increase again towards the end of the decade to match its real value in 1995 (250 Reais at 2007 prices, Figure 2). The minimum wage, however, declined relative to the average wage, notably in the informal sector (Figure 3 ), which reduced over time its (shadow) wage gap with respect to the formal sector.

Figure 4 plots the Kernel density estimator for the distribution of wages of formal sector employees before and after (bold line) the May 1995 minimum wage hike which increased its level from 70 Reais (nominal value) to 100 Reais, almost a 43% increase. Figure 5 provides the same distributions for informal sector employees.

Both distributions shift to the right after the introduction of the minimum wage. Notice that

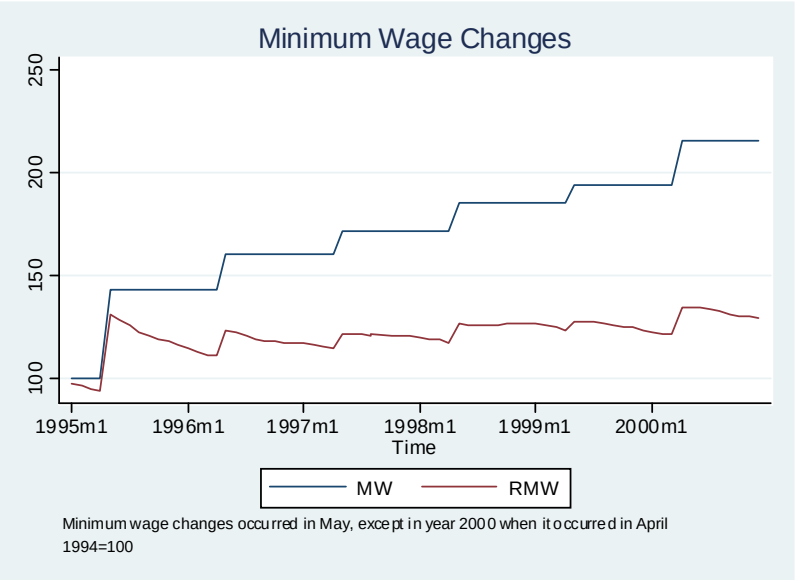


Figure 2: Evolution of real and nominal minimum wage. Brazil: 1995-2000.

also the spikes of the two distributions move to the right. Significantly, it is precisely the distribution of wages for informal sector workers that displays spikes in correspondence to the old and new level of the minimum wage. This is precisely a lighthouse effect. Thus, our data also suggest that wages in the informal sector increase as a result of minimum wage hikes, as pointed out by the literature on the lighthouse effect. The model of the next section highlights a new sorting mechanisms for rationalizing these changes.

# 3 A Shadow Sorting Model and the Minimum Wage

## 3.1 Shadow Employment and Worker's Sorting

We consider an economy with a measure one of heterogenous workers and two sectors. The worker type is indicated by $x$, where $x$ refers to labor market productivity and its value is drawn from a continuous cumulative distribution function $F$ with support $[x_{\min}, x_{\max}]$. $x$ is a fixed time invariant worker characteristic, with $x_{\min} > 0$.

There are two sectors in the labor market: the regular sector and the shadow sector. The gross value of production of each worker is indicated with $x$ where $x$ is an idiosyncratic component of productivity. In the regular sector firms pay a production tax $\tau$ in every period in which they

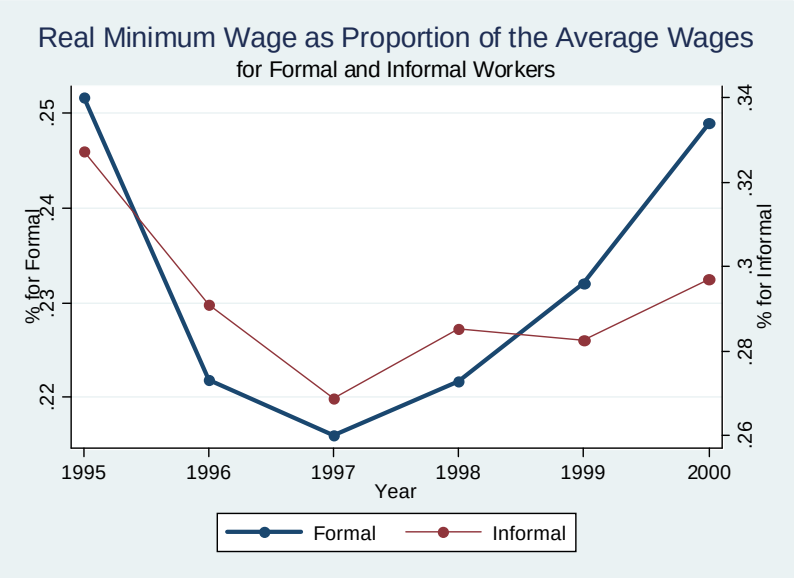


Figure 3: Real minimum wage as proportion of the average wage

employ a worker, so that the productivity of the worker is $x - \tau$. In the shadow sector the tax is evaded and there is an instantaneous monitoring rate equal to $\rho$. Conditional on being monitored in the shadow sector, the shadow job is destroyed. Both regular and shadow jobs are otherwise exogenously destroyed at rate $\lambda$[3].

Firms can freely post a vacancy in either sector. We focus on single jobs, and each firm is made of one job. Posting a vacancy in the regular sector costs $k_g$ per period while in the shadow sector costs $k_b$. There is free entry of firms in both sectors and the equilibrium value of a vacancy is driven down to zero. Job creation characterizes the labor demand side of the model.

The labor supply is governed by the workers' sorting behavior. Workers are endowed with a unit of time and freely decide whether its is optimal to search and work in the shadow sector or in the legal sector. Entering a sector is a full-time activity, and workers cannot simultaneously work and/or search in both sectors. In the legal sector there is a specific unemployed income (the unemployment benefits) which is not available in the shadow sector.

Labor markets are imperfect, and there are market frictions in each sector. We follow the main matching literature (Pissarides, 2000), and assume that the meeting of vacant jobs and unemployed workers is regulated by a matching function with constant returns to scale. Different matching

[3]In the simulations we also assume that conditional on $\lambda$ striking, regular jobs need to pay a firing tax $T$.

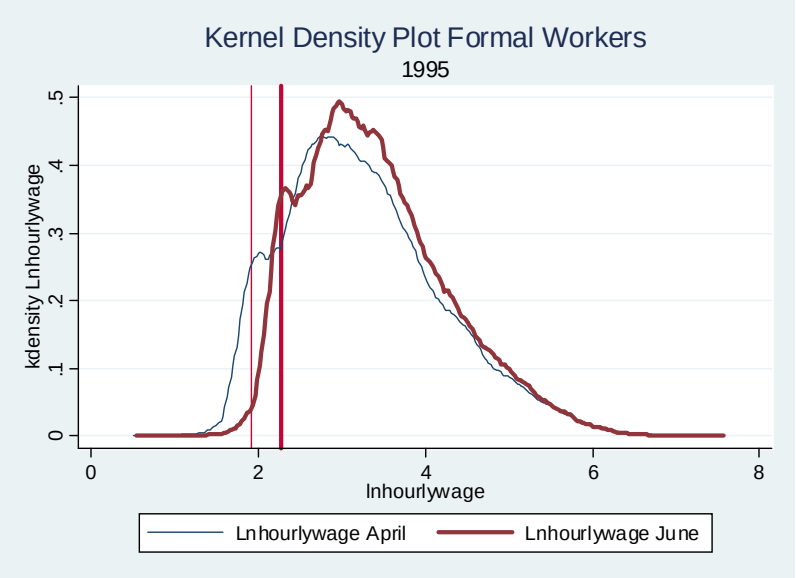


Figure 4: Density of hourly wage in the formal sector

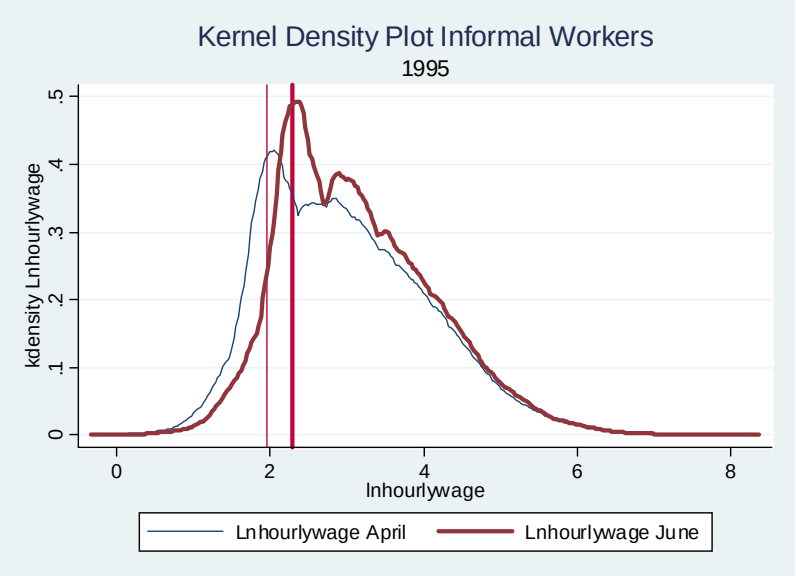


Figure 5: Density of hourly wage in the informal sector

functions exist in different sectors. In what follows we let with $v_g$ and $v_b$ be the number of vacancies in both sectors, and $u_g$ and $u_b$ the number of unemployed job seekers. The matching function in each sector is indicated with

$$m^i(u^i, v^i) \qquad i = g, b$$

with positive first derivative and negative second derivative. As in the traditional matching models with constant returns to scale, the transition rate depends on the relative number of traders, a sufficient statistics which is indicated with $\theta^i = \frac{v^i}{u^i}$. Specifically, the transition rate for firms is indicated with $q^i(\theta^i) = \frac{m(u^i, v^i)}{v^i}$ with $q'(\theta^i) < 0$, while the transition rate for workers is indicated with $\alpha'^i(\theta^i) = \theta^i q(\theta^i)$ with $\alpha' > 0$.

### 3.2 Wages and Minimum Wages

Successful matches in each sector enjoy a pure economic rent. We assume that in each sector wages obtain a fraction $\beta$ of the marginal productivity $x$. Yet, in the legal sector, and only in the legal sector, a minimum wage $w_{\min}$ is fully enforced. This implies that wages in the legal sector are

$$w^g(x) = \begin{cases} \beta(x - \tau) & \text{if } \beta(x - \tau) \geq w_{\min} \\ w_{\min} & \text{if } \beta(x - \tau) < w_{\min} \end{cases}$$

In other words wages obtain a fraction $\beta$ of the marginal product as long such value is above the minimum wage. In the shadow sector the wage is simply the fraction $\beta$ of the marginal product and there is no minimum wage

$$w^b(x) = \beta x$$

We solve the model in four steps. First, we present the value functions and the asset equations and define the key equilibrium conditions without the minimum wages. Second, we solve the workers' sorting behaviour in partial equilibrium, taking as given job creation (the labor demand side of the model) and the transition rate in each market. The effects of the minimum wage on the workers' sorting behaviour is discussed in some details. Next, we discuss the extension of the model when the job creation condition is taken into account. The purpose of the theoretical analysis is to derive a set of predictions linked to the moonlight effects in the aftermath of the minimum wage. For more analytical details of the model we refer to Boeri-Garibaldi (2006).

### 3.3 Value Functions with a non binding minimum wage

We first assume that the minimum wage is not binding, so that it is irrelevant for our analysis. We introduce a binding minimum wage in the next subsections. The value of a filled job in the legal sector with productivity $x$ reads

$$rJ^g(x) = x - \beta x - \tau + \lambda[V^g - J^g(x)]$$

where $\tau$ is the tax rate, $V^g$ is the value of a vacancy and $r$ is the pure discount rate. Jobs are destroyed at the exogenous rate $\lambda$, and $\beta x$ is the wage rate.

Unemployment is a full time activity, and workers cannot work in the shadow sector during an unemployment spell. The value of unemployment in the legal sector for a worker of type $x$ is

$$rU^g(x) = b + \alpha^g(\theta)[W^g(x) - U^g(x)]$$

where $b$ is the specific unemployed income (the unemployment benefits), and $W^g(x)$ is the value of the job for a type $x$. The value of a job in the legal sector is

$$rW^g(x) = \beta(x - \tau) + \lambda[U^g(x) - W^g(x)].$$

Posting vacancies in the legal sector is costly, and yields a per period return equal to $-k_g$. Conditional on meeting a worker, at rate $q^g(\theta^g)$, the firm gets the expected value of a job. In formula, its expression reads

$$rV = -k_g + q^g(\theta^g)\left[E\left[J(z) \mid z \in \Omega\right] - V\right]$$

where the expectation is taken with respect to the productivity of workers that search in the legal sector. The expression $\Omega$ refers to the support of workers who search in the legal sector.

The value functions for jobs in the shadow sector are similarly defined. The main differences is that in the shadow sector firms do not pay the production tax $\tau$ and the job is monitored and destroyed at rate $\rho$. Further, there is no specific unemployed income $b$. The four value functions read

$$\begin{aligned}
rJ^b(x) &= x - \beta x + (\lambda + \rho)[V^b - J^b(x)] \\
rW^b(x) &= \beta x + (\lambda + \rho)[U^b(x) - W^b(x)] \\
rU^b(x) &= \alpha^b(\theta^b)[W^b(x) - U^b(x)] \\
rV^b &= -k_b + q^b(\theta^b)\left[E\left[J^b(z) \mid z \in \Omega^c\right] - V^b\right]
\end{aligned}$$

where $\Omega^c$ is support of workers that search in the shadow sector.

### 3.4 Equilibrium Conditions Without the Minimum Wage

There are three key equilibrium conditions

- Free entry and job creation in the legal sector ($JC^g$), which implies that the value of a vacancy be zero

$$V^g = 0$$

  This equation will determine market tightness in the legal sector $\theta^g$

- Free entry and job creation in the shadow sector ($JC^b$), which implies that the value of a vacancy be zero

$$V^b = o$$

  This equation will determine market tightness in the shadow sector $\theta^b$

- Workers' sorting ($Sort$). If we assume that workers' sorting satisfies the reservation property, (a feature that holds in equilibrium) the labor supply is described by the marginal worker with productivity $R$, where $R$ is the productivity level for which the worker is indifferent between the two sectors, so that

$$U^g(R) = U^b(R)$$

Using the reservation property, the three key conditions are

$$\alpha^b(\theta^b)[W^b(R) - U^b(R)] = b + \alpha^g(\theta^g)[W^g(R) - U^g(R)] \tag{Sort}$$

$$\frac{k_g}{q^b(\theta^b)} = \frac{\int_R^{x^u} J^g(z)dF(z)}{1 - F(R)} \tag{JC$^g$}$$

and

$$\frac{k_b}{q^b(\theta^b)} = \frac{\int_{x_l}^{R} J^b(z)dF(z)}{F(R)} \tag{$JC^b$}$$

The first condition states that the marginal worker is indifferent between searching for a job in the legal or in the shadow sector. The second condition states that the total search costs in the legal sector are identical to the expected value of a job. The last condition has a similar interpretation, but refers to the shadow sector. The system determines the three endogenous variables $\theta^g, \theta^b$ and $R$

### 3.5 Stocks

The model is closed by determining the stock of workers into the four possible labor market states: unemployment and employment in each of the two sectors. If we indicate with $u^i$ the stock of unemployed in each sector and with $n^i$ the stock of employed, we have

$$u^g + u^b + n^g + n^b = 1$$

Workers' sorting in the baseline model implies that the share of workers in the shadow sector is $F(R)$ while the remaining $1 - F(R)$ workers search in the legal sector. Unemployment and employment in the shadow sector read respectively

$$\begin{aligned} u^b &= \frac{(\lambda + \rho)F(R)}{\lambda + \rho + \alpha^b(\theta^b)} \\ n^b &= \frac{\alpha^b(\theta^b)F(R)}{\lambda + \rho + \alpha^b(\theta^b)} \end{aligned}$$

In the legal sector, the unemployment and the employment rate are respectively

$$\begin{aligned} u^g &= \frac{\lambda(1 - F(R))}{\lambda + \alpha^b(\theta^b)} \\ n^g &= \frac{\alpha^b(\theta^b)(1 - F(R))}{\lambda + \alpha^b(\theta^b)} \end{aligned}$$

We are now in a position to formally define the equilibrium of the model.

**Definition 1** *Baseline Equilibrium. The equilibrium is obtained by a triple $R, \theta^g$ and $\theta^b$ and a vector of stock variables that satisfy the value functions $J^i, W^i, U^i, V^i$ $(i = g, b)$, and i) Workers' sorting, ii) Job Creation in the legal sector, iii) Job Creation in the shadow sector, iv) balance flow conditions.*

### 3.6 Solving the worker's sorting behavior

The worker chooses the sector in which to enter on the basis of a simple comparison between the value of unemployment in each sector. Using an expression for the value of employment $W$, the value of unemployment in both sectors reads respectively

$$\begin{aligned} rU^b(x) &= \alpha^b(\theta^b)\frac{\beta x}{r + \lambda + \rho + \alpha^b(\theta^b)} \\ rU^g(x) &= b + \alpha^g(\theta^g)\frac{\beta[x - \tau] - b}{r + \lambda + \alpha^g(\theta^g)} \end{aligned}$$

Figure 6 shows the two value functions in partial equilibrium as a function of the productivity $x$. The differences in the two curves are driven by the intercept (which is negative in the legal sector) and by the slope. We make two key assumptions in this respect:

- Taxation is large enough relative to unemployment benefits. This implies that the intercept of $U^g$ is negative in Figure 6.
- Monitoring is large enough. We formally assume that $\rho > \frac{(r+\lambda)(\alpha^g-\alpha^b)}{\alpha^g}$. This implies that the value function of $U^g$ is steeper than $U^b$.

From the value functions, we can get an expression for the reservation productivity. The reservation value $R$, if it exists, is the crossing point of the two lines. Its formal expression, when considering $\alpha^g$ and $\alpha^b$ exogenous and constant is

$$R = \frac{\tau\alpha^g\beta(r+\lambda+\rho+\alpha^b) - b(r+\lambda)(r+\lambda+\rho+\alpha^b)}{\alpha^g\rho + (r+\lambda)(\alpha^b-\alpha^g)}$$

Existence in partial equilibrium requires $R > 0$, and the two key assumptions above ensure that $R$ is positive. The equilibrium that we are considering implies that shadow jobs are occupied by workers with low skills, in line with the evidence discussed in Boeri and Garibaldi (2005) and further discussed in Section 4 of this paper. The sorting of workers by productivity in the two sectors, is a key premise of our theoretical analysis

**Remark 1** *When there is no minimum wage, shadow jobs are occupied by relatively low skilled workers.*

There are several results in the partial equilibrium setting, and are graphically obtained by shifts and movements of the two lines. They can be summarized as follows:

- An increase in unemployment benefits reduces the reservation productivity $R$, so that more people search in the legal market. At given job finding rates, an increase in unemployment benefits increases legal employment. Formally, ithis result is obtained by noting that

$$\frac{\partial R}{\partial b} < 0$$

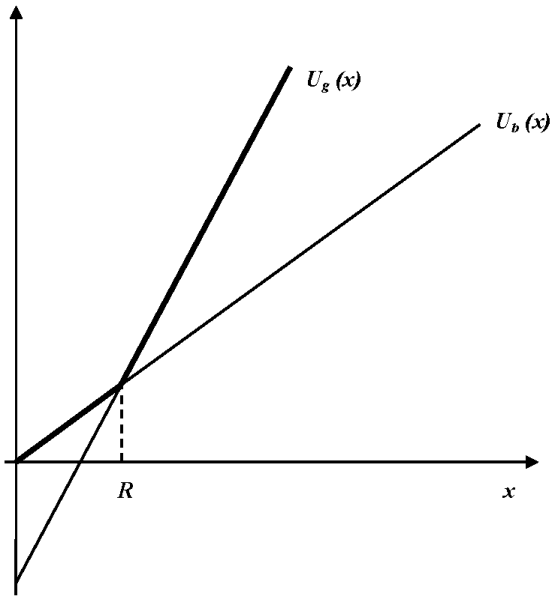


Figure 6: Workers' sorting in partial equilibrium (with constant job finding rate)

- An increase in taxation increases shadow employment. This is the standard mechanism that taxation moves away people from the regular sector into the shadow employment. Formally, it is obtained by observing that

$$\frac{\partial R}{\partial \tau} > 0$$

- An increase in the monitoring rate reduces shadow employment. An increase in the monitoring rate reduces the return from shadow employment and induces people to search in the legal market. Formally, this result is obtained by noting that i

$$\frac{\partial R}{\partial \rho} < 0$$

### 3.7 Workers' sorting with a binding minimum wage

The presence of the minimum wage modifies the workers' sorting behaviour. The minimum wage is by definition paid only in the formal sector. As a result, the worker's value of unemployment after the introduction of a mnimum wage is

$$rU^g(x) = b + \frac{\beta[x-\tau]-b}{r+\lambda+\alpha^g(\theta^g)}$$

$$rU^g(x) = \begin{cases} b + \alpha^g(\theta^g)\frac{\beta[x-\tau]-b}{r+\lambda+\alpha^g(\theta^g)} & \text{if } \beta(x-\tau) \geq w_{\min}; \\ b + \alpha^g(\theta^g)\frac{w_{\min}-b}{r+\lambda+\alpha^g(\theta^g)} & \text{if } \beta(x-\tau) < w_{\min} \end{cases}$$

The introduction of the minimum wage implies that the value function has a kink at $x^k = \frac{w_{\min}}{\beta} - \tau$; Since the minimum wage applies only to formal sector jobs, we say that the minimum wage is binding if $x^k > R$. In what follows we assume that is indeed the case. Figure 7 displays this case. When the minimum wage is binding, the two value function cross twice, and the partition of workers across the two sectors is governed by two reservation values. In particular, define as $R_l$, the reservation productivity such that

$$\begin{aligned} rU^b(R_l) &= b + \alpha^g(\theta^g)\frac{w_{\min}-b}{r+\lambda+\alpha^g(\theta^g)} \\ \frac{r\beta R_l}{r+\lambda+\rho+\alpha^b(\theta^b)} &= b + \alpha^g(\theta^g)\frac{w_{\min}-b}{r+\lambda+\alpha^g(\theta^g)} \end{aligned}$$

The introduction of the minimum wage changes the allocation of workers across the two sectors. Specifically, with the introduction of the minimum wage workers allocate to the regular sector if $x < R_l$ and $x > R$; Conversely, workers belong to the shadow sector if $R_l < x < R$. The allocation is displayed in Figure 8. We are now in a position to derive three key implications of our analysis

**Proposition 1** *The introduction of the minimum wage changes the skill composition of workers in the shadow sector and in the regular sector. In particular, the skill composition of workers in the shadow sector increases*

**Proposition 2** *Moonlight effect. The introduction of the minimum wage increases the average wage in the shadow sector*

**Proposition 3** *The introduction of the minimum wage increases the supply of low skill workers in the regular sector*

Proposition 1 is straightforward and can be easily seen with the help of Figure 8. The minimum wage introduces an additional threshold in the allocation of workers across skills. Workers in the regular sector are now not only the workers with individual productivity above $R$ but also workers with productivity below $R_l$. Conversely, workers in the shadow sectors are those workers that have productivity between the two reservation values. The latter observation leads immediately

to Proposition 2. The model presented implies a moonlinght effect in the shadow sector. In the aftermath of the introduction of the minimum wage the average wage in the shadow sector increases. To see the moonlight effect more formally, let $\overline{w}_1^s$ and $\overline{w}_o^s$ be the average wage in the shadow before and afte r the introduction of the minimum wage. It is immediate to see that $\overline{w}_1^s > \overline{w}_o^s$

$$\overline{w}_1^s = \beta \int_{R_l}^{R} x dF(x) > \beta \int_{0}^{R} x dF(x) = \overline{w}_o^s$$

Proposition 3 is a corollary of the moonlight effect. Very low skill workers are now supplying their skills in the regular sector. This clearly reduces the average skills of workers in the regular sector. Note that all these results are obtained in partial equilibrium, at given labor demand. The next section briefly illustrates how these results may change when labor demand is properly taken into account.

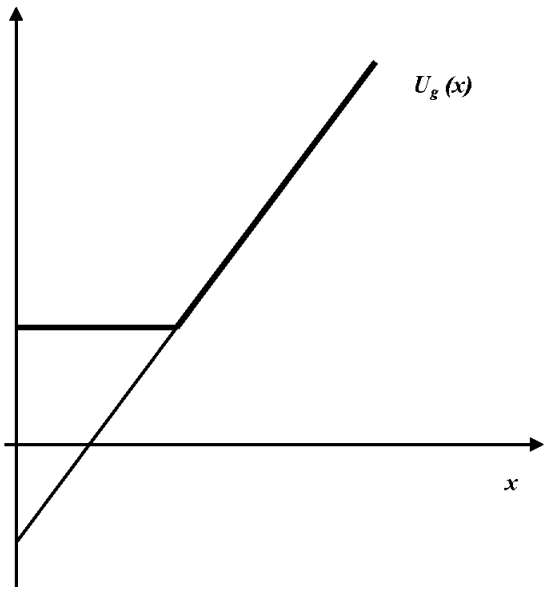


Figure 7: The Effect of the Minimum wage on the value of a job in the regular sector

### 3.8 Labor Demand, Job Creation and General Equilibrium

Job creation in both sectors is obtained by obtaining the average value of the job in both sectors. Boeri and Garibaldi (2005) show the analytics of the model in details and also how to obtain the

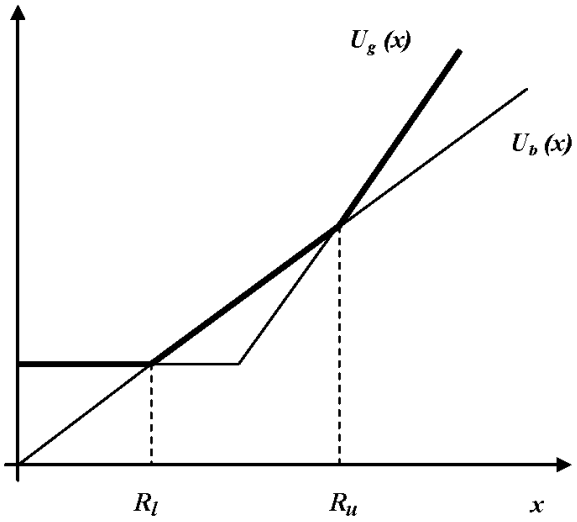


Figure 8: The labour supply effects of the introduction of the minimum wage

general equilibrium. In this paper we only discuss the results qualitatively. Market tightness $\theta^i$ and the associated job finding rates $\alpha_i$ depend on the various parameters, as well as on the workers' sorting behavior. Most parameters have a direct effect on job creation, plus an indirect effect via the reservation productivity $R$. Formally, we can write

$$\begin{aligned} \alpha^g(\theta^g) &= \alpha^g(R(.), b, r, \lambda, \beta, w^{\min})) \\ \alpha^b(\theta^b) &= \alpha^b(R(.), \rho, \lambda, \beta, w^{\min})) \end{aligned}$$

where the symbol $R()$ suggests that $R$ is itself an endogenous variable. Some important comparative static results follow

- An increase in the reservation productivity $R$ increases market tightness and the job finding rates in both sectors. An increase in $R$ increases the average quality of the workforce in both sectors, so that firms naturally respond by posting more vacancies per unemployed. This result is important, and shows how sorting affects job creation.

- An increase in unemployment benefits $b$, at given reservation productivity $R$, reduces job creation in the legal sector. This is the standard adverse effect of unemployment income on job creation, an effect that works mainly through the wage rule.

- An increase in taxation, at given reservation productivity $R$, reduces job creation in the legal sector. This is also a textbook adverse labor demand effect of taxation

- An increase in the monitoring rate $\rho$, at given reservation productivity $R$, reduces job creation in the shadow sector. Higher monitoring rate acts as an increase in the destruction rate on shadow jobs.

- The introduction of the minimum wage reduces job creation in the legal sector. This result is important in the context of this paper and is farily straighforward. On the labor demand side of the market, the introduction of the minimum wage is akin to an increase in the expected costs related to the job. This increase in costs naturally reduces job creation in the shadow sector. At the same time, since the average skill increases in the shadow sector, job creation in the shadow sector increases

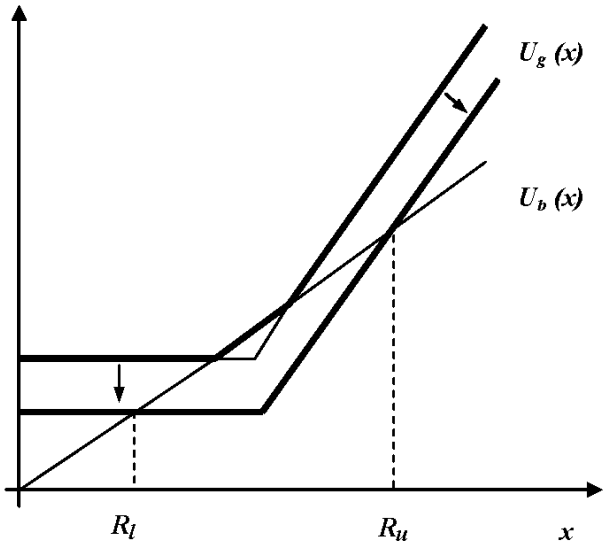


Figure 9: Minimum Wage with the Labor Demand Effects

The general equilibrium of the model is obtained by solving for the two reservation productivities and market tightness levels $R \;\; R_l, \theta^g, \theta^b$ . While we refer to Boeri and Garibaldi (2005) for the analytical details of the analysis, in what follows we just consider the qualitative effects of the introduction of the minimum wage. Figure 9 show the qualitative results of the analysis. The main effect of the introduction of the minimum wage is the reduction of the value of unemloyment in

the regular sector. This cost effect is akin to a downard shift of the value of unemployment in the regular sector. As the figure shows, these general equilibrium effects have two further effects on the shadow sector. FIrst, the shadow sector expand since the relative value of a job in the regular sector is reduced vis-a-vis the shadow sector. Second, the skill composition of the workforce in the shadow sector increases. These two effects can be summarized in the following propositions.

**Proposition 4** *Moonlight effect is also present in the general equilibrium setting, since the average skills of workers in the shadow sector increase.*

**Proposition 5** *The size of the shadow sector increases with the introduction of the minimum wage*

In the next section we go back to the data and consider whether these implications are consistent with the evidence on the moonlight effect in Brazil.

# 4 Back to the Data

We proceed in three steps in order to test the empirical relevance of our explanation of the lighthouse effect. First we obtain some empirical proxy for the skill level of the workers in the two sectors. Our model has a key prediction in terms of allocation of skills between the two sectors and the baseline model implies that the shadow sector has a lower skill composition than the formal sector. Next, we analyse the correlation of these proxies (fixed-effects in a wage equation) with observed data on educational attainments. Finally we look at transitions between formal and informal sector at different deciles of the distribution of fixed-effects and we provide an estimate of the fraction of the change in wages in the informal sectors which can be accounted for by sorting effects, as opposed to lighthouse effects.

## 4.1 Fixed effects estimates

Exploiting the longitudinal structure of data we estimate for each year in our sample the following regression

$$\log(w_{it}) = a_i + D_t + TEN_{it}$$

where $a_i$ is an individual fixed-effect, $D_t$ is a set of time (monthly) dummies, and $TEN_{it}$ captures individual time-varying effects, notably tenure on any job. This equation was estimated only on workers being employed for at least two-periods covered by our data in order to recover the fixed effect. The latter should offer a measure of observable and unobservable time-invariant differences in the skills of individuals.

Table 3 displays the correlation of these estimated fixed effects with the stated years of schooling. As shown by the table, the correlation is always positive and statistically significant. This is fairly encouraging as we expect skills to be positively correlated to schooling

**Table 3. Correlation of fixed effects and years of schooling**

| Year | Correlation |
|---|---|
| 1995 | 0.55 |
| 1996 | 0.56 |
| 1997 | 0.55 |
| 1998 | 0.53 |
| 1999 | 0.55 |
| 2000 | 0.56 |

Figure 10 displays the distributions of fixed effects for the populations of formal sector (dark histograms) and informal sector workers in 1995. Similar charts are available from the authors for the other years covered by data and provide the same information. In essence, informal sector workers do have systematically lower fixed effects than formal sector workers. This is in line with the substantive assumptions of our model.

## 4.2 Shifts across the shadow margins

Our model explains the increase in wages in the informal sector following a minimum wage hike as a byproduct of sorting of workers across the shadow margins. Proposition (4) and (5) make this point clear. An increase in the minimum wage induces shifts of low-skilled workers from the informal to the formal sector and shifts of relatively high skill workers from the formal sector to the informal sector. This increases the average productivity of workers in the informal sector inducing higher job creation in this segment.

A test of the implications of our model is therefore in looking at transitions across the shadow margins by skill. Table 4 displays transitions probabilities (FI means from formal sector to informal

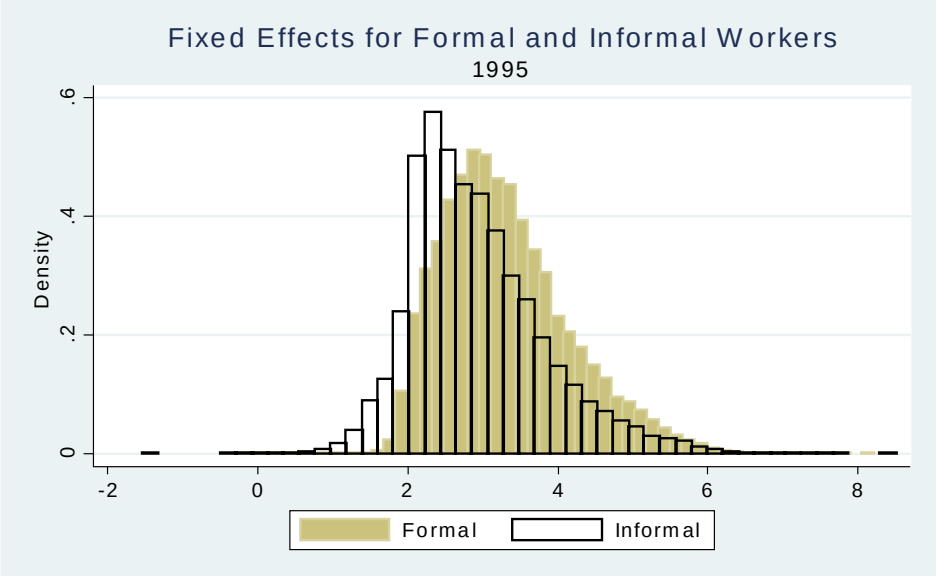


Figure 10: Distributions of fixed effects for the formal and imformal populations of workers

sector jobs, IF vice versa) by decile of the fixed-effects distribution. The transitions are from the state occupied by the individuals in the 3 months before the minimum wage hikes to the state occupied in the 6 months after the increase in the minimum wage. We consider only one-way transitions, e.g., we rule out workers going from formal to informal and then back to formal sector jobs

**Table 4. Transitions across sectors by decile of the FE distribution**

| **Deciles from the lowest to the highest** | **FI** | **IF** |
|---|---|---|
| 1 | 17.04 | 9.70 |
| 2 | 10.18 | 18.63 |
| 3 | 6.67 | 20.37 |
| 4 | 5.96 | 22.90 |
| 5 | 4.46 | 22.41 |
| 6 | 4.71 | 24.31 |
| 7 | 3.61 | 24.10 |
| 8 | 3.17 | 23.85 |
| 9 | 3.38 | 25.18 |
| 10 | 3.35 | 29.36 |

The key message provided by the table is that shifts from the formal to the informal sector involves mainly the lowest skill types of the distribution of fixed effects in the formal sector. Amost one worker out of five in the lowest decile experience a transition from the formal to the informal sector, compared with one out of thirty in the upper deciles of the skill distributions. Sizeable transitions from the informal to the formal sector occur at all deciles of the fixed-effect distribution in the informal sector, and are increasing with our proxy for skills.

We interpret these results as broadly in line with the qualitative sorting effects predicted by our model.

Finally, Table 5 decomposes the total variation in wages in the informal sector between lighthouse and sorting effects. In particular, it disantangles the changes in the average wage of those workers who have been continuously working in the informal sector before and after the minimum wage hike (the lighthouse component) from the residual sorting component, which is associated to persons moving from the informal sector to the formal sector and vice versa, i.e., we use the following decomposition

$$\Delta\bar{w}_I \ = \Delta\bar{w_{IC}}s_c \ + \Delta\bar{w_{IS}}(1-s_c)$$

where $\Delta\bar{w}_I$ denotes the variation in the average wage in the informal sector between the three months preceding the change in the minimum wage (generally January, February and March) and the three months after the minimum wage hike (June, July and August); $\Delta\bar{w_{IC}}$ denotes the same variation conditioning on workers who have been working through the entire period in the informal sector, $s_c$ is the stayer coefficient of a transition matrix mapping flows from the informal to the formal sector, while $\Delta\bar{w_{IS}}$ denotes the variation in the minimum wage for those who were in the informal sector either before or after the minimum wage change but not in both periods. In other words, we consider that the signal effect is relevant for wage renegotiation for those working continuously in the informal sector, while changes in the average wage between those leaving the informal sector after the minimum wage hike and those entering subsequently capture the compositional effects related to the sorting of workers by skills.

The message delivered by Tables is that the sorting component explains at least one third of the increase in the average wage in the informal sector. Significantly this contribution is increasing over time, while the lighthouse effects in some years (e.g., 2000) is negative.

**Table 5. Sorting and lighthouse effects: assessing the contributions**

| **1995** | Δ | **1996** | Δ |
|---|---|---|---|
| Total variation | 32.8 | Total variation | 21.7 |
| contribution lighthouse | 22.2 (68%) | contribution lighthouse | 13.7 (63%) |
| contribution sorting | 10.6 (32%) | contribution sorting | 8.0 (37%) |

| **1999** | Δ | **2000** | Δ |
|---|---|---|---|
| Total variation | 6.4 | Total variation | 6.0 |
| contribution lighthouse | 3.9 (41%) | contribution lighthouse | -0.5 (-7%) |
| contribution sorting | 2.5 (39%) | contribution sorting | 6.4 (107%) |

# 5 Final Remarks

The increasing literature on minimum wages in developing countries documented that, contrary to standard predictions of economic theory, average wages in the informal sector tend to react positively to an increase in the minimum wage in the formal sector. This effect has been explained as a lighthouse effect, that is a signal offered by the minimum wage to wage setting in the informal sector, but this explanation has never been tested empirically.

In this paper we provided an alternative explanation for this puzzle which is based on sorting of workers across the shadow margins. We also extended a general equilibrium model of the labor market to characterise the type of sorting that it is expected to occur after a minimum wage hike. Finally, we went back to the data to test the key implications of the model. We found that the skill composition of outflows from the informal sector to the formal sector and vice versa are broadly in line with the implications of the model, predicting an increase in te average skill level in the informal sector. Thus, sorting of workers across the two margins always contribute to increasing the average wage between the period before and after the minimum wage hike. This sorting effect explains at least one third of the total increase in average wages in the informal sector in the three months after the increase in the minimum wage with respect to the conditions prevailing before

the minimum wage hike.

Further work may look at the implications of sorting for other moments of the distribution of wages in the informal sector and apply alternative decomposition techniques to evaluate the effects of minimum wage changes over the entire distribution of wages in the informal sector. It would also be important to anayse more in detail wage setting in the informal sector possibly relying on ad-hoc surveys eliciting wage and working conditions in this segment of the economy.

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