

THE LIGHTHOUSE EFFECT AND BEYOND

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A large body of empirical literature indicates that, contrary to predictions from economic theory, wages in the informal sector increase after a minimum wage hike. This phenomenon was so far explained as a byproduct of a signal (a lighthouse) conveyed by statutory minima to wage setting in the informal sector. A simple matching model shows that an increase in wages in the informal sector may also be induced by significant sorting and composition effects between the formal and the shadow sectors in the aftermath of the increase in the minimum wage. Using data on Brazil, we find that sorting accounts for at least one third of the increase in average wages in the informal sector after a minimum wage hike. This contribution of endogenous sorting to wage dynamics in the informal sector is also increasing over time.

JEL Code: J30

Keywords: minimum wage, lighthouse effect, sorting

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 retain substantial bargaining power, more than offsetting the negative supply shock.

In this paper we provide an alternative rationale for the positive effect of minimum wages on wages in the informal sector on the basis of the shadow sorting model provided by Boeri and Garibaldi (2005), where workers and firms self-select

Note: We thank Rita Almeida, Jaspas Hoeke, and Sara Lemos for helping us in gathering Brazil data.

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Review of Income and Wealth © 2011 International Association for Research in Income and Wealth
Published by Blackwell Publishing, 9600 Garsington Road, Oxford OX4 2DQ, UK and 350 Main St, Malden, MA, 02148, USA.

themselves into a formal and an informal sector. 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 very low skilled workers into the formal sector. These composition effects induce an increase in the average productivity and 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 and wages in the formal sector. These results also hold in general equilibrium, but they depend on structural parameters of the model.

We test our alternative explanation by drawing on data from Brazil, allowing tracking of 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 flows of the least skilled from the informal to the formal sector, reducing employment in the former). 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 a minimum wage hike. Moreover, we find that this contribution of sorting to wage adjustment 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 analyzes the mechanics behind the lighthouse effect, obtaining a set of propositions that can be taken to the data. Section 4 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 is not enforced in a 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_0^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 sector wages. This adjustment mechanism prevents full employment losses only if there is perfect labor mobility between the two sectors and wages are flexible in the informal sector. Insofar as workers losing their job have no access or limited access to unemployment benefits (Maloney

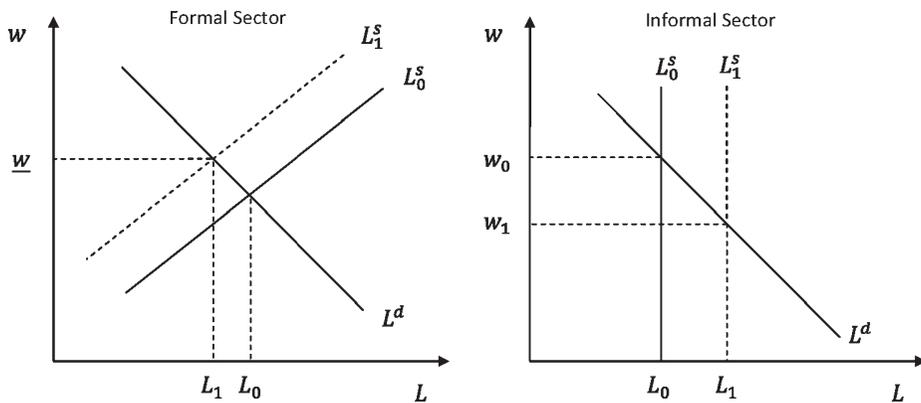


Figure 1. The Standard Theoretical Prediction

and Nunez, 2003; Gindling and Terrell, 2004a), 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. Notwithstanding measurement problems, this effect seems rather robust to alternative specifications of the wage equation in the two sectors (Amadeo *et al.*, 2000; Neri *et al.*, 2000; Maloney and Nunez, 2003), notably in Brazil where data on the informal sector are considered to be more reliable.

There is also some evidence of positive effects of minimum wage rises on informal sector wages in other Latin American countries. Maloney and Nunez (2003), in particular, found that in Mexico, Argentina, Uruguay, Brazil, Chile, Honduras, and Colombia, “the influence of the minimum wage appears more significant in the informal sector than in the formal sector.” Gindling and Terrell (2004), however, did not find evidence of any lighthouse effect in Costa Rica.

The interpretation provided by this literature for these spillover effects of minimum wages on wage setting in the shadow sector 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 also have monopsonistic power 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.

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 as a benchmark 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 (Camargo, 1989; Neri, 1997; Amadeo *et al.*, 2000). However, it is doubtful that in the 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 of the positive effect of minimum wage hikes on informal sector wages call into play substitution effects. Employers could react to a minimum wage hike, by substituting formal workers with informal ones, and the stronger demand for informal workers could more than offset the increase of labor supply in this sector, inducing a rise in informal sector wages (Fajnzylber, 2001).

Other scholars challenged the idea that the informal sector offers jobs of lower quality than those available in the formal sector (Maloney, 1999). According to these theories, an increase in the minimum wage could make the formal sector a more attractive destination for some informal sector workers and actually induce a decrease in the supply of labor in the informal sector, generating an increase in informal sector wages.

2.2. Definitions and Data

A widely used definition of the informal sector 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, 1994; Lubell, 1991; 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 legal activities. Our notion of informal or shadow employment is one of a lawful activity were it reported to tax authorities and subject to work regulations.

We rely on data from 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 six of the major Brazilian metropolitan areas, namely Belo Horizonte, Porto Alegre, Recife, Rio de Janeiro, Salvador, and São Paulo. 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.

Although the increase of the informality in the Brazilian labor market dates back to the 1980s, it was only in the 1990s that it became really significant, independent 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. Moreover, labor regulations in terms of holidays and leave periods are typically not respected for these workers. In the PME there is a specific question asking the interviewed person whether she/he has the work card, so that it is possible to disentangle formal from informal sector workers.¹ This distinction, however, does not apply to the civil servants. Hence, in our analysis we focus only on private sector employees.

¹Many authors also consider the self-employed as belonging to the informal sector. In our analysis we concentrate on dependent employment.

TABLE 1
DESCRIPTIVE STATISTICS ON THE TWO SECTORS

	Total		% Women		Age (years)		Education (years)		Hourly Wage (Reais)	
	Formal	Informal	Formal	Informal	Formal	Informal	Formal	Informal	Formal	Informal
1995	208,242	86,038	36.6%	43.3%	33.2	30.0	7.5	6.0	3.3	2.8
			(0.48)	(0.49)	(10.97)	(12.84)	(4.06)	(3.81)	(0.88)	(0.89)
2000	198,166	97,216	39.9%	45.2%	33.8	31.9	8.6	7.4	3.8	3.3
			(0.49)	(0.50)	(10.85)	(12.77)	(3.91)	(3.91)	(0.81)	(0.85)

Note: Standard deviations in parentheses.

Table 1 provides some descriptive statistics on formal versus 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 (Ulyssea, 2006) reach estimates as high as 40 percent, so that it is quite possible that our data undersample informal 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 of the Brazilian Government to increase the educational attainment 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 by Boeri and Garibaldi (2005), which is extended below.

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

The first minimum wage was introduced in Brazil in 1940 and was established in each region by a Wage Commission whose main concern was to provide subsistence remuneration to a single adult worker for a normal working day. Since 1984 the minimum wage is set at the national level and is adjusted periodically by the Ministério do Trabalho e Emprego, mainly to preserve its purchasing power. There is also a norm, which is rarely enforced, prohibiting the use of minimum wage as an indexation parameter for social transfers.

Our analysis covers the period 1995 to 2000 as we concentrate on years in which there was no 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 six-year period, the level of the real hourly minimum wage experienced a large increase in May 1995 and then declined, but increased again toward 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 in the informal sector (Figure 3), as the latter experienced stronger wage growth than the formal sector.

Figure 4 plots the Kernel density estimator for the distribution of (real) wages of formal sector employees before and after (bold line) the May 1995 minimum wage hike, which increased its level from 70 to 100 Reais, a 40 percent increase in real terms. 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 the spikes of the two distributions move as well to the right. Significantly, it is precisely the distribution of wages for informal sector workers

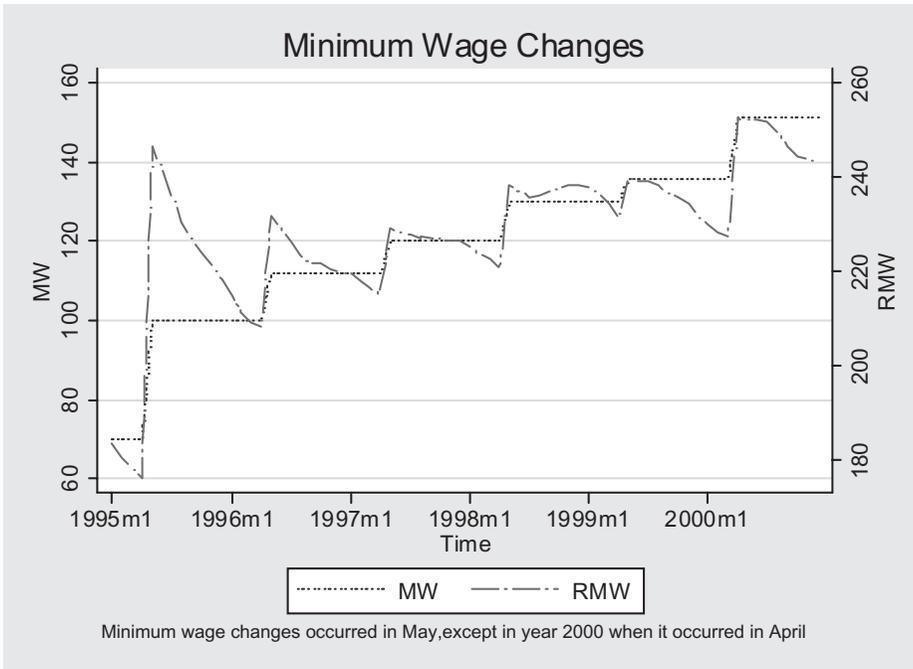


Figure 2. Evolution of Real (Dotted Line) and Nominal (Continuous Line) Minimum Wage; Brazil: 1995–2000

that displays a marked spike in correspondence to the old and new levels of the minimum wage. Thus, our data suggest that wages in the informal sector increase as a result of minimum wage hikes, in agreement with the literature on the lighthouse effect. These spikes are broadly in accordance with the lighthouse explanations, although there is also a spike well above the new level of the minimum wage, which was not as pronounced before the regulatory change.

The model in the next section provides a new sorting mechanism potentially able to rationalize these changes in the wage distribution occurring above the minima.

3. A SHADOW SORTING MODEL AND THE MINIMUM WAGE

3.1. *Shadow Employment and Workers' Sorting*

We consider an economy with a measure one of heterogeneous 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. In the regular sector firms pay a production tax τ in every period in which they employ a worker, so that the net value of production of the worker is $x - \tau$.

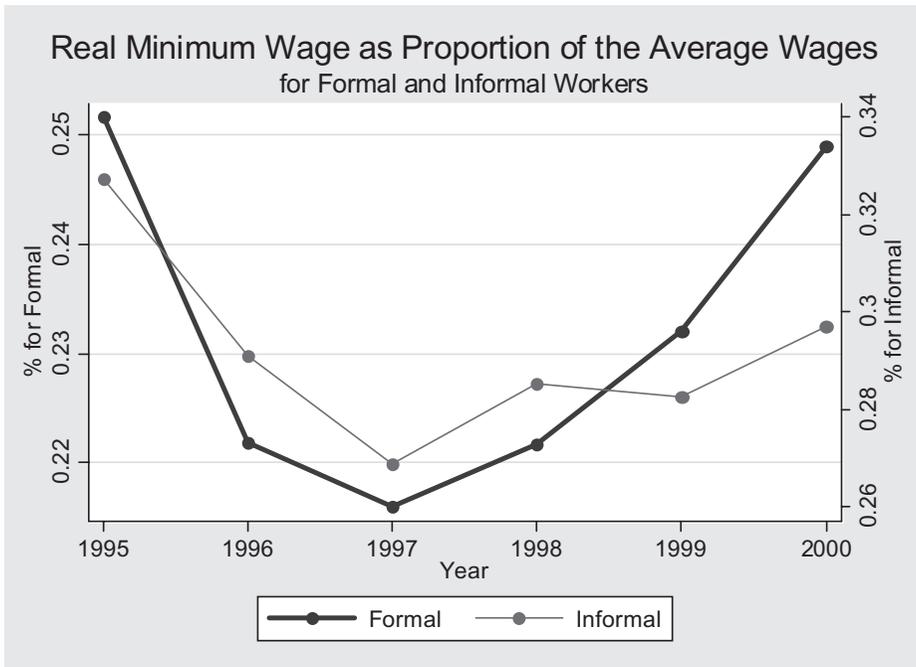


Figure 3. Real Minimum Wage as Proportion of the Average Wage

In the shadow sector, the tax is evaded and there is an instantaneous monitoring rate equal to ρ . Conditional on being monitored in the shadow sector, the shadow job is destroyed. Both regular and shadow jobs are otherwise exogenously destroyed at rate λ .² Let us denote, with subscripts “ l ” and “ s ,” legal and shadow jobs, respectively.

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_l per period while in the shadow sector costs k_s . There is free entry of firms in both sectors and the equilibrium value of a vacancy is driven down to zero. This job creation condition 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 it 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 (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

²In the simulations we also assume that conditional on λ striking, regular jobs need to pay a firing tax T .

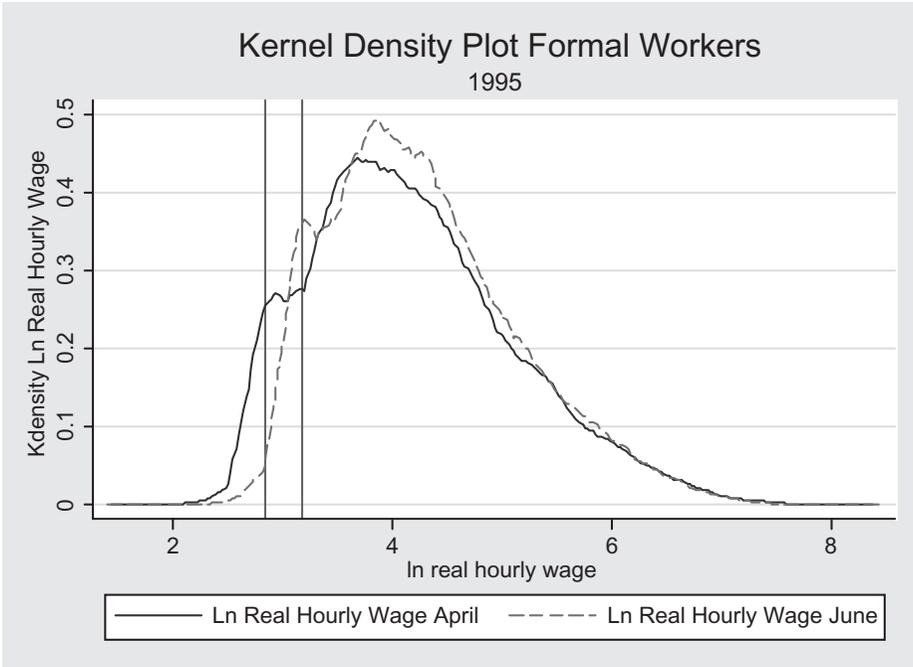


Figure 4. Kernel Density of Hourly Wages in the Formal Sector Before (Continuous Line) and After (Dotted Line) the Minimum Wage Hike

function with constant returns to scale. Different matching functions exist in different sectors. The matching function in each sector is indicated with

$$m^i(u^i, v^i) \quad i = l, s,$$

where v and u denote vacancies and unemployment, respectively. 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 by $\theta^i = \frac{v^i}{u^i}$. Specifically, the transition rate for firms is indicated by $q^i(\theta^i) = \frac{m(u^i, v^i)}{v^i}$ with $q'(\theta^i) < 0$, while the transition rate for workers is indicated by $\alpha^i(\theta^i) = \theta^i q(\theta^i)$ 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 β of the total surplus from the job $S(x)$, where the exact definition of the surplus will be introduced shortly. We indicate with $w_\beta^i(x)$ the bargained wage in each sector. 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

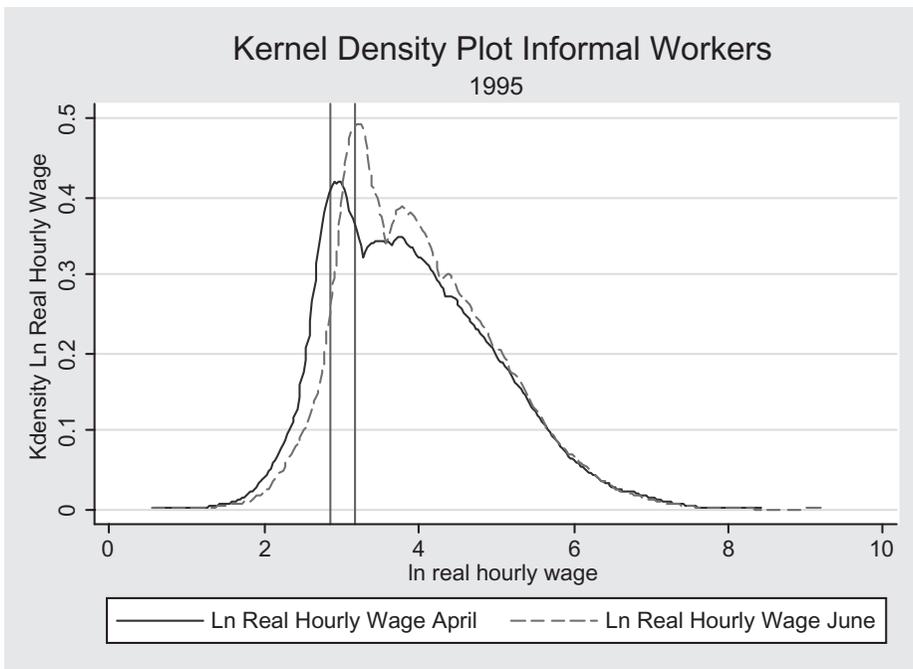


Figure 5. Kernel Density of Hourly Wages in the Informal Sector Before (Continuous Line) and After (Dotted Line) the Minimum Wage Hike

$$w'(x) = \begin{cases} w'_\beta(x) & \text{if } w'_\beta(x) \geq w_{\min} \\ w_{\min} & \text{if } w'_\beta(x) < w_{\min} \end{cases}$$

In other words wages obtain a fraction β of the total surplus as long as such value is above the minimum wage. In the shadow sector the wage is always a fraction β of total surplus and there is no minimum wage:

$$w^s(x) = w'_\beta(x).$$

We solve the model in three steps. First, we present the value functions and the asset equations without the minimum wage. Second, we solve the workers' sorting behavior with a binding minimum wage 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 behavior is discussed in some detail and the lighthouse result is obtained. Third, we discuss the extension of the model when the job creation and the general equilibrium effects are taken into account. The purpose of this theoretical analysis is to derive a set of testable predictions on the effects on informal sector wages and employment of minimum wage hikes.

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. The value of a filled job in the legal sector with productivity x reads

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

where τ is the tax rate, V^l is the value of a vacancy, and r is the pure discount rate. Jobs are destroyed at the exogenous rate λ , and $w_\beta^l(x)$ is the bargained 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

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

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

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

Posting vacancies in the legal sector is costly, and yields a flow return equal to $-k_l$. Conditional on meeting a worker, at rate $q^l(\theta^l)$, the firm gets the expected value of a job. Thus, the value of a vacant post reads

$$rV = -k_l + q^l(\theta^l)[E[J(z) | z \in \Omega] - V],$$

where the expectation is taken with respect to the productivity of workers that search in the legal sector. The expression Ω 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 are that in the shadow sector firms do not pay the production tax τ and the job is monitored and destroyed at rate ρ . Further, there is no specific unemployed income b . The four value functions, in the informal sector, read

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

$$rW^s(s) = w_\beta^s(x) + (\lambda + \rho)[U^s(x) - W^s(x)]$$

$$rU^s(x) = \alpha^s(\theta^s)[W^s(x) - U^s(x)]$$

$$rV^s = -k_s + q^s(\theta^s)[E[J^s(z) | z \in \Omega^s] - V^s],$$

where Ω^s is support of workers that search in the shadow sector.

As anticipated in the previous section, wages in each sector are the outcome of a bilateral matching process and workers get a fraction β of the total surplus, so that

$$[W^i(x) - U(x)] = \beta S^i(x)$$

where

$$S^i(x) = W^i(x) - U^i(x) + J^i(x) - V^i(x).$$

In words, the total surplus is the value of a match net of the outside income of employers and workers.

3.4. Solving the Workers' Sorting Behavior

Using the value functions defined above, and holding the value of a vacancy constant and equal to zero (a condition that is actually satisfied in general equilibrium), the surplus of a match for a legal job with productivity x is

$$(r + \lambda)S^l(x) = x - \tau - b - \alpha^l(\theta^l)[W^l(x) - U^l(x)].$$

Recalling that wages get a fraction β of the total surplus, the previous expression reads

$$(1) \quad S^l(x) = \frac{x - \tau - b}{r + \lambda + \beta\alpha^l(\theta^l)}.$$

Similarly, the surplus in the shadow sector is

$$(2) \quad S^s(x) = \frac{x}{r + \lambda + \rho + \beta\alpha^s(\theta^s)}.$$

Note that in the surplus expressions the matching rates are constant with respect to the idiosyncratic productivity x , and the surplus from the job is an increasing linear function of the match specific productivity x . Using (1) and (2) it is possible to obtain the value of unemployment in the two sectors as a function only of flow values

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

$$U^s(x) = \frac{\alpha^s(\theta^s)\beta x}{r + \lambda + \rho + \beta\alpha^s(\theta^s)}.$$

Figure 6 shows the two value functions in partial equilibrium as a function of gross 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:

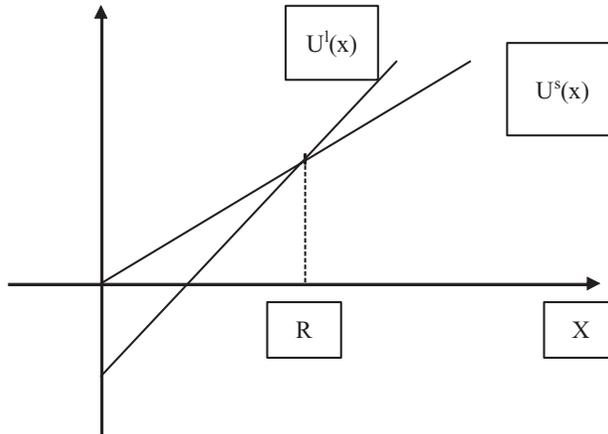


Figure 6. Workers' Sorting in Partial Equilibrium (with constant job finding rates)

- A1. Taxation is large enough relative to unemployment benefits. This implies that the intercept of U^l is negative in Figure 6. We thus formally assume that $b(r + \lambda) < \tau\alpha'\beta$.
- A2. Monitoring is large enough to satisfy the condition $\rho > \frac{(r + \lambda)\beta(\alpha^l - \alpha^s)}{\alpha^l\beta}$. This implies that the value function of U^l is steeper than U^s .

From the value functions, we can get an expression for the reservation productivity. The decision about the sector to work in is made while unemployed (there is no on-the-job search in this model), hence it is based on the two values of unemployment functions. The reservation value R , if it exists, is the crossing point of the two lines. Existence in partial equilibrium requires that $R > 0$, and the two key assumptions A1 and A2 above ensure that R is indeed 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 provided in Section 4 of this paper. The sorting of workers by productivity in the two sectors is a key premise of our theoretical analysis.³

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

Finally, using again (1) and (2), note that the bargained wage in the two sectors is

³There are several comparative static results. An increase in unemployment benefits reduces the reservation productivity R , so that $\frac{\partial R}{\partial b} < 0$; An increase in taxation increases shadow employment. Formally, it is obtained by observing that $\frac{\partial R}{\partial \tau} > 0$. An increase in the monitoring rate reduces shadow employment. Formally, this result is obtained by noting that $\frac{\partial R}{\partial \rho} < 0$.

$$w_{\beta}^l(x) = \frac{\beta(x - \tau - b)(r + \lambda + \alpha'(\theta^l))}{r + \lambda + \beta\alpha'(\theta^l)}$$

$$w_{\beta}^s(x) = \frac{\beta(x)(r + \lambda + \rho + \alpha^s(\theta^s))}{r + \lambda + \rho + \beta\alpha^s(\theta^s)}$$

Unsurprisingly, the wage is an increasing function of the match specific productivity, x .

3.5. Workers' Sorting with a Binding Minimum Wage

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

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

The introduction of the minimum wage implies that the wage function and the associated value function have a kink at $w^l(x^k) = w_{\min}$ as displayed in Figure 7.

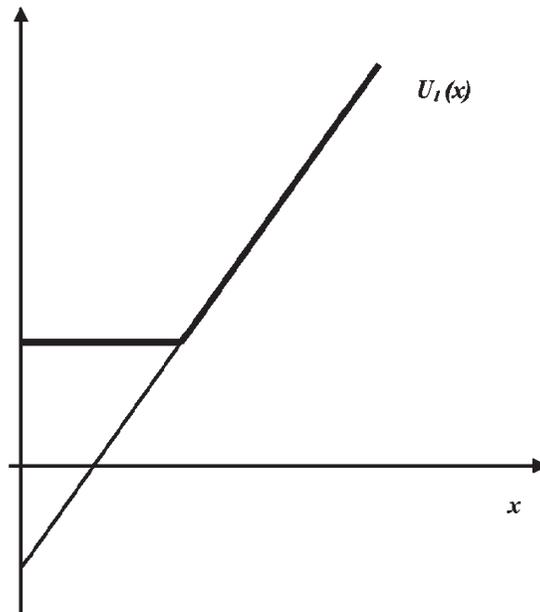


Figure 7. The Effect of the Minimum Wage on the Value of a Job in the Regular Sector

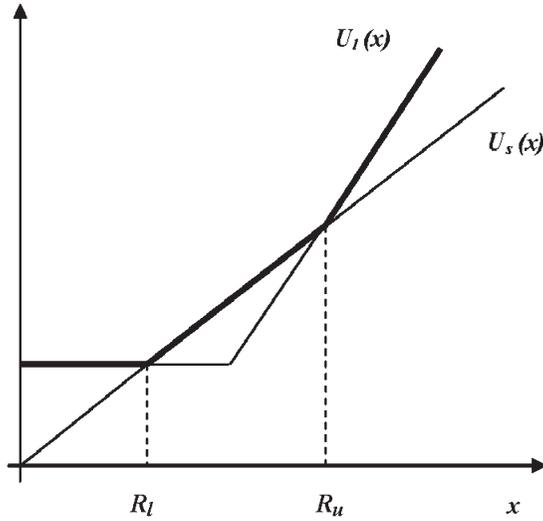


Figure 8. The Labor Supply Effects of the Introduction of the Minimum Wage

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 this is indeed the case. When the minimum wage is binding, the two value functions 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 workers are indifferent between the shadow sector and the legal sector at a minimum wage

$$rU^s(R_l) = b + \alpha'(\theta^l) \frac{w_{\min} - b}{r + \lambda + \alpha'(\theta^l)}$$

$$\frac{\beta\alpha^s(\theta^s)R_l}{r + \lambda + \rho + \beta\alpha^s(\theta^s)} = b + \alpha'(\theta^l) \frac{w_{\min} - b}{r + \lambda + \alpha'(\theta^l)}$$

The introduction of the minimum wage changes the allocation of workers across the two sectors and two value functions cross twice, as displayed in Figure 8. Specifically, with the introduction of the minimum wage, workers allocate to the regular sector if $x < R_l$ and $x > R_u$, where from now onward we indicate the the lower threshold with subscript l and the upper threshold with subscript u . In light of this allocation, workers belong to the shadow sector if $R_l < x < R_u$. The two threshold R_l and R_u are the solutions to the following two equations:

$$(3) \quad \frac{\beta\alpha^s(\theta^s)R_l}{r + \lambda + \rho + \beta\alpha^s(\theta^s)} = b + \alpha'(\theta^l) \frac{w_{\min} - b}{r + \lambda + \alpha'(\theta^l)}$$

$$\frac{\beta\alpha^s(\theta^s)R_u}{r + \lambda + \rho + \beta\alpha^s(\theta^s)} = b + \frac{\beta\alpha^l(\theta^l)(R_u - \tau - b)}{r + \lambda + \alpha'(\theta^l)}$$

We are now in a position to derive three key implications of our analysis.

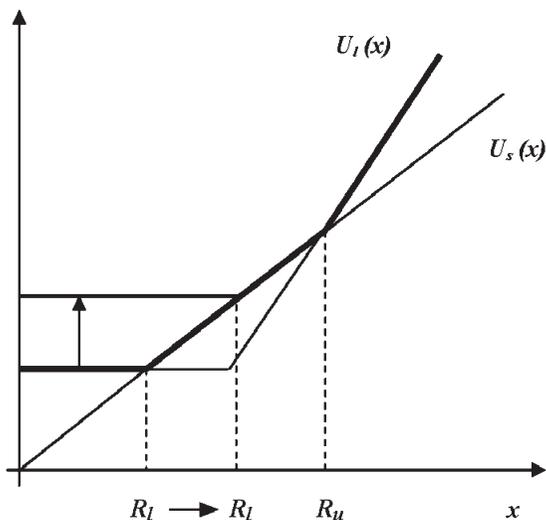


Figure 9. The Effect of a Marginal Increase in the Minimum Wage

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 average skill level of workers in the shadow sector increases.*

Proposition 2. *Lighthouse effect. A marginal increase in the minimum wage increases the average wage in the shadow sector.*

Proposition 1 is straightforward and can be easily seen with the help of Figure 9. 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_u 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 lighthouse effect in the shadow sector. An increase in the minimum wage increases the threshold R_l while it has no direct impact on the threshold R_u . The key result for the lighthouse effect is obtained by the fact that $\frac{\partial R_l}{\partial w_{\min}} > 0$ in equation (3). To prove the results analytically, let us define the average wage in the shadow sector as the expected wage conditional on being in the shadow interval

$$\bar{w}_s = \frac{\int_{R_l}^{R_u} w_{\beta}^s(x) dF(x)}{F(R_u) - F(R_l)}.$$

Note that in partial equilibrium $\frac{\partial R_u}{\partial w_{\min}} = 0$ so that the lighthouse effect immediately follows. Formally, this is obtained by the differentiation of the previous expression with respect to w_{\min} to obtain

$$\frac{\partial \bar{w}_s}{\partial w_{\min}} = \frac{f(R_l) \int_{R_l}^{R_u} [w_\beta^s(x) - w_\beta^s(R_l)] dF(x)}{[F(R_u) - F(R_l)]} > 0,$$

that is certainly positive since the wage bargained is an increasing function of the idiosyncratic productivity x .

Proposition 3. *An increase in the minimum wage increases the supply of low skill workers in the regular sector.*

Proposition 3 is a corollary of the lighthouse 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.

3.6. Labor Demand, Job Creation, and General Equilibrium

Job creation in both sectors is obtained by solving for the average value of the job in both sectors. Boeri and Garibaldi (2005) show the analytics of the model in detail and also how to obtain the general equilibrium. In this paper we derive the key equilibrium conditions and discuss the results with an illustrative simulation.

In general equilibrium there are four key equilibrium conditions:

- Free entry and job creation in the legal sector (JC^l), which implies that the value of a vacancy is zero:

$$V^l = 0.$$

This equation will determine market tightness in the legal sector θ^l .

- Free entry and job creation in the shadow sector (JC^s), which implies that the value of a vacancy is zero:

$$V^s = 0.$$

This equation will determine market tightness in the shadow sector θ^s .

- Workers' sorting. If the minimum wage is binding, the labor supply is described by two marginal workers with productivity R_l and R_u , respectively, and the sorting conditions are such that

$$U^l(R_l) = U^s(R)$$

$$U^l(R_u) = U^s(R_u).$$

The four conditions can be written as:

$$(Sort) \quad \alpha^s(\theta^s)[W^s(R_u) - U^s(R_u)] = b + \alpha^l(\theta^l)[W^l(R_u) - U^l(R_u)]$$

$$(4) \quad \alpha^s(\theta^s)[W^s(R_u) - U^s(R_u)] = b + \alpha^l(\theta^l) \frac{w_{\min} - b}{r + \lambda + \alpha^l(\theta^l)}$$

$$(JC^s) \quad \frac{k_l}{q^l(\theta^l)} = \frac{\int_0^{R_l} J^l(z) dF(z)}{F(R_l)} + \frac{\int_{R_u}^{x^u} J^l(z) dF(z)}{1 - F(R_u)}$$

and

$$(JC^s) \quad \frac{k_s}{q^s(\theta^s)} = \frac{\int_{R_l}^{R_u} J^s(z) dF(z)}{F(R_u) - F(R_l)}.$$

The first two conditions are the sorting equations obtained in partial equilibrium, but are to be solved now also with endogenous labor demand. The third 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 four endogenous variables θ^s , θ^l , R_l , and R_u .⁴

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

$$u^l + u^s + n^l + n^s = 1.$$

Workers' sorting in the baseline model implies that the share of workers in the shadow sector is $F(R_u) - F(R_l)$ while the workers in the legal sector are the two fractions $F(R_l)$ and $1 - F(R_u)$ workers. Unemployment and employment in the shadow sector read, respectively,

$$u^s = \frac{(\lambda + \rho)[F(R_u) - F(R_l)]}{\lambda + \rho + \alpha^s(\theta^s)}$$

$$n^s = \frac{\alpha^s(\theta^s)[F(R_u) - F(R_l)]}{\lambda + \rho + \alpha^s(\theta^s)}.$$

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

$$u^l = \frac{\lambda(1 - F(R_l) + F(R_u))}{\lambda + \alpha^s(\theta^s)}$$

$$n^l = \frac{\alpha^l(\theta^l)(1 - F(R_l) + F(R_u))}{\lambda + \alpha^s(\theta^s)}.$$

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

⁴Note that the previous conditions assume that the minimum wage is binding and that the kink in the wage function $w_{\beta}^l(x_k) = w_{\min}$ takes place between the two reservation values R_l and R_s . When solving the model numerically one needs to take care that such condition is satisfied.

Definition 1. Baseline Equilibrium. The equilibrium is obtained by a n -tuple R_l, R_u, θ^l , and θ^s and a vector of stock variables that satisfy the value functions J^i, W^i, U^i, V^i ($i = l, s$), and (i) workers' sorting, (ii) job creation in the legal sector, (iii) job creation in the shadow sector, (iv) balance flow conditions.

Formally, the general equilibrium defined above is a solution to the following system of four equations in four unknowns $R_l, R_u, \theta^l, \theta^s$:

$$\frac{\beta\alpha^s(\theta^s)R_l}{r + \lambda + \rho + \beta\alpha^s(\theta^s)} = b + \alpha^l(\theta^l)\frac{w_{\min} - b}{r + \lambda + \alpha^l(\theta^l)}$$

$$\frac{\beta\alpha^s(\theta^s)R_u}{r + \lambda + \rho + \beta\alpha^s(\theta^s)} = b + \frac{\beta\alpha^l(\theta^l)(R_u - \tau - b)}{r + \lambda + \alpha^l(\theta^l)}$$

$$\frac{c}{q(\theta^s)} + \frac{(\tau + w_{\min})}{r + \lambda} = \frac{1}{r + \lambda} \int_0^{R_l} (1 - F(z)) dz$$

$$+ \frac{(1 - \beta)}{(r + \lambda + \beta\alpha^l(\theta^l))(1 - F(R_u))} \int_{R_l}^{R_u} (1 - F(z)) dz$$

$$\frac{c}{q(\theta^s)} = \frac{(1 - \beta)}{(r + \lambda + \rho + \beta\alpha^s(\theta^s))} \frac{R_u F(R_u) - R_l F(R_l) - \int_{R_l}^{R_u} F(z) dz}{F(R_u) - F(R_l)}.$$

3.7. An Illustrative Simulation

Market tightness θ^i and the associated job finding rates α_i , that were held constant in partial equilibrium analysis, 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 productivities R_l and R_u .

The model cannot be easily solved analytically but it can be simulated. Note that in general equilibrium the labor demand effects are likely to induce a reduction in the demand for jobs as the minimum wage is increased. Yet, for the purposes of this paper, it is still possible that the partial equilibrium effects around the sorting conditions R_l hold (Proposition 2 above), as the increase in the minimum wage is likely to attract people into the legal sector, thus inducing a change in the skill composition of people in the shadow sector. By looking at the first equation, for given market tightness θ^l and θ^s above suggests that this is indeed the case. Yet in general equilibrium it is certainly no longer true that $\frac{\partial R_u}{\partial w_{\min}} = 0$, so there is an additional effect coming from the change in the upper threshold. In addition, in general equilibrium an increase in the minimum wage induces a likely reduction in the firms' willingness to create jobs, since the increase in the average wage comes with an increase in expected costs. All these effects

TABLE 2
INCREASE IN MINIMUM WAGE IN GENERAL EQUILIBRIUM

Parameters		$w_{\min} = 0.1$		$w_{\min} = 0.12$	
		Legal	Shadow	Legal	Shadow
Discount rate	r	0.03	0.03	0.03	0.03
Separation rate	λ	0.15	0.15	0.15	0.15
Unemployed income	b	0.10	0.10	0.10	0.10
Matching elasticity	η^j	0.5	0.5	0.5	0.5
Monitoring rate	ρ	0.06	0.06	0.06	0.06
Production tax	τ	0.15	0.15	0.15	0.15
Matching function constant	A^i	0.8	0.6	0.8	0.6
Workers' surplus share	β	0.5	0.5	0.5	0.5
Search costs	c	0.45	0.45	0.45	0.45
<i>Equilibrium values</i>					
Sorting 1	R_l	0.21	0.21	0.24	0.24
Sorting 2	R_u	0.97	0.97	0.87	0.87
Market tightness	θ	0.52	0.20	0.50	0.19
<i>Aggregate statistics</i>					
Unemployment	u	0.162	0.141	0.165	0.143
Employment	n	0.34	0.34	0.39	0.29
Average wage	w	0.138	0.067	0.145	0.075

Note: Distribution is exponential with parameters $B = 2.0$ and $A = 2.0$.

Source: Authors' calculations.

imply that the general equilibrium effect of an increase in the minimum wage is not indeed obvious and also depends on the distribution of jobs $F(x)$ around the thresholds.

The general equilibrium of the model is obtained by solving for the two reservation productivities and market tightness levels R_l , R_u , θ^l , θ^u . Table 2 presents an illustrative simulation for two economies that are identical with respect to all the parameters, the only exception being that the minimum wage increases from 0.1 to 0.12 in the second economy. The simulation shows that in the aftermath of the increase in the minimum wage the average wage increases not only in the regular sector, but also in the shadow sector. The mechanics of the result in the illustrative case depend entirely on the increase in R_l since the upper threshold R_u is reduced by the increase in the minimum wage.

The simulation suggests that an increase in the minimum wage may induce an increase in wages in the shadow sector, but in general depends on some specific structural parameters of the model, and also on the distribution of productivity around the threshold. Note also that this simulation suggests a decline in the size of the shadow sector in the aftermath of the increase in the minimum wage. In the next section we go back to the data and consider whether the implications of the theoretical analysis are consistent with evidence on Brazil.

4. BACK TO THE DATA

We proceed in three steps in order to test the empirical relevance of our explanation for the effects of minimum wage hikes on informal sector wages. First,

TABLE 3
CORRELATION OF FIXED EFFECTS AND YEARS OF SCHOOLING

Year	Correlation
1995	0.49
1996	0.50
1997	0.51
1998	0.49
1999	0.51
2000	0.51

Note: All correlations are significant at 1%.

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 analyze the correlation of these proxies (fixed-effects in a wage equation) with observed data on educational attainments and we use flows between the informal sector and the formal sector at different skill levels to evaluate—within a differences-in-differences approach—the empirical relevance of the predictions of our model. Finally we provide an estimate of the fraction of the change in wages in the informal sector which can be accounted for by sorting behavior, as opposed to lighthouse effects.

4.1. Fixed Effects Estimates

Exploiting the longitudinal structure of data, we estimated for each year in our sample the following wage regression

$$\log(w_{it}) = a_i + D_t + \beta EDU_{it} + \gamma TEN_{it} + \varepsilon_{it},$$

where w_{it} are hourly wages, a_i is an individual fixed-effect, D_t is a set of time (monthly) dummies, EDU and TEN capture years of education and tenure, respectively, i.e. individual time-varying effects, and ε is the error term. This equation was estimated only on workers being employed for at least two periods covered by the longitudinal structure of our data described in Section 2, in order to recover the individual fixed effects. 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 reported 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.

Figure 10 displays the distribution of fixed effects for formal sector (dark histograms) and informal sector workers in 1995.⁵ Informal sector workers appear to have systematically lower fixed effects than formal sector workers. This is in line with the substantive assumptions of our model.

⁵Similar diagrams are available from the authors for the other years covered by data and provide the same information.

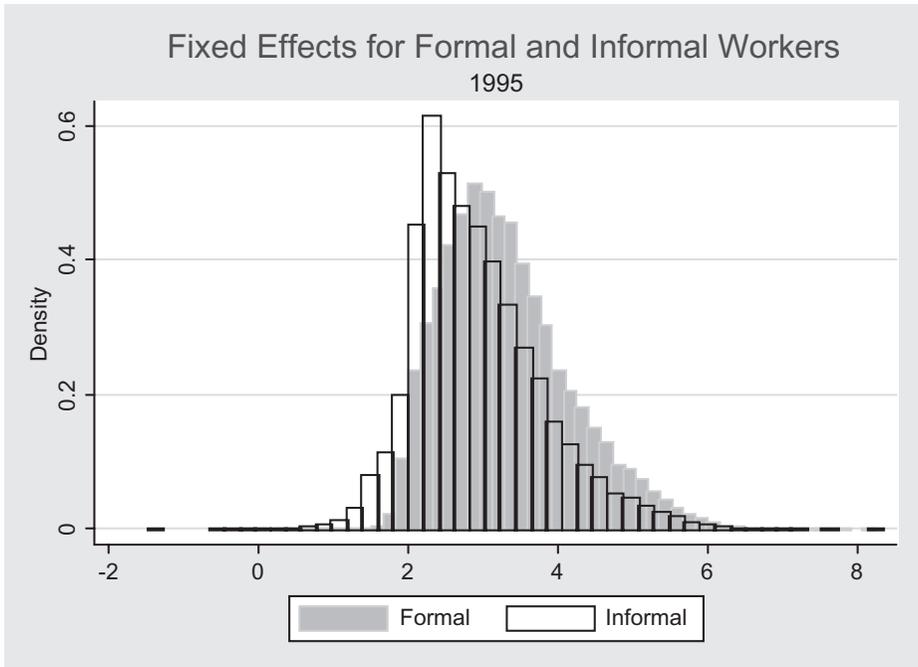


Figure 10. Distribution of the Fixed Effects in the Formal (Shaded) and Informal Employment Populations

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 by-product of sorting of workers across the shadow margins. Propositions (1) and (2) make this point clear. An increase in the minimum wage induces shifts of low-skilled workers from the informal to the formal sector. This effect holds both in partial and in general equilibrium. Shifts in labor demand may also originate shifts of relatively high skill workers from the informal sector to the formal sector, partly offsetting the effects of sorting at the lower threshold on average productivity and wages in the informal sector in the aftermath of an increase in the minimum wage. Alternatively labor demand may shift down the upper threshold, inducing shifts of workers from the informal to the formal sector. The model also predicts a decline in the size of the informal sector, as displayed by our simulation, and an increase in average educational attainments, after an increase in the minimum wage.

A test of the implications of our model is therefore in looking at transitions across the shadow margins at different skill levels. Table 4 performs a differences-in-differences analysis of these shifts. In particular, *before* refers to the period January–February–March, while *after* refers to the three months after the changes in the minimum wage (May–June–July). We performed this analysis for all the years covered by our data, but we display here only those referred to 1995, the year in which there was the strongest increase in the minimum wage (a 40 percent increase in real terms).

TABLE 4
DIFFERENCES-IN-DIFFERENCES ANALYSIS OF THE SORTING HYPOTHESIS

	IF Flows (%)			FI Flows (%)			
	Before	After	Δ	Before	After	Δ	
Low skill (1st decile fe distribution)	10.84	11.06	0.22	Low skill (1st decile fe distribution)	15.95	17.00	1.05
Medium skill (5th decile fe distribution)	23.91	21.98	-1.93	High skill (10th decile fe distribution)	3.37	2.99	-0.38
$\Delta\Delta$			2.15	$\Delta\Delta$			1.43
	Size (number of full-time employees, 000s)			Average Education (years)			
	Before	After	Δ (%)	Before	After	Δ	
Informal	10,426	10,255	-1.64	Informal	5.95	6.05	0.10
Formal	29,195	28,552	-2.20	Formal	7.35	7.52	0.17
$\Delta\Delta$			0.56	$\Delta\Delta$			-0.07

In the first panel on the left-hand side we compare changes in outflow rates from informal to formal jobs at the lowest end (first decile) and in the middle (fifth decile) of the distribution of fixed effects in the shadow sector. According to the predictions of our model, shifts across the shadow margins should take place either in the first decile of the skill distribution (the partial equilibrium effect) or at the tenth decile (the general equilibrium effect). Thus differences in outflow rates from the informal to the formal sector at the fifth decile control for factors (e.g. seasonal effects) which may have affected all outflow rates, independently of sorting effects. We find that flows from the first decile increase while those originating from the fifth decile decline. In double difference terms, we observe an increase in outflow rates of the least skilled of about 20 percent (2.15 base points). This is in line with the implications of our model.

A similar analysis is carried out for flows from the formal to the informal sector. Here in general equilibrium we should observe, according to our model, flows only at the lowest end of the skill distribution of formal sector workers. Consistent with this empirical prediction, we consider the tenth decile of the distribution of fixed effects in the formal sector as a control group. The overall, double-difference effect, is once again positive and sizeable (1.5 base points, i.e. a 20 percent increase) in line with the implications of our model.

The two lowest panels compare the evolutions of size and educational attainments in the two sectors. We find that employment in both sectors decreases after the minimum wage hike, but slightly more so in the formal sector than in the informal sector. Notice that the standard theory predicts that the informal sector should experience a positive supply shock, absorbing workers from the formal sector. We instead find that both sectors decline. The reduction in the size of the shadow sector is consistent with the sorting hypothesis. However, it should be stressed that the theoretical propositions refer to steady state comparisons while our empirical analysis is unavoidably concentrated on the short-run, which may involve a temporary rise of unemployment.

TABLE 5
SORTING AND LIGHTHOUSE EFFECTS: ASSESSING THE CONTRIBUTIONS

1995		1996	
	Δ		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		2000	
	Δ		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%)

Insofar as educational attainments are concerned, we find that the average number of years of schooling is increasing in both sectors. This is also consistent with the sorting hypothesis.

4.3. A Simple Decomposition

Finally, Table 5 decomposes the total variation in wages in the informal sector between lighthouse and sorting effects. In particular, it disentangles 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 with persons moving from the informal sector to the formal sector and vice versa, i.e. we use the following decomposition:

$$\frac{\sum_{i \in e_1^I} w_{i1}^I}{e_1^I} - \frac{\sum_{i \in e_0^I} w_{i0}^I}{e_0^I} \equiv \Delta \bar{w}^I \equiv \left\{ \sum_{i \in e_1^I \& i \in e_0^I} (w_{i1}^I - w_{i0}^I) \left(1 - \frac{o^I}{e_0^I} \right) \right\} + \left\{ \frac{\sum_{i \in e_1^I \& i \notin e_0^I} w_{i1}^I}{e_1^I} \frac{e_1^I}{i^I} - \frac{\sum_{i \in e_0^I \& i \notin e_1^I} w_{i0}^I}{e_0^I} \frac{e_0^I}{o^I} \right\} = \{\text{lighthouse}\} + \{\text{sorting}\}$$

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 (January, February, and March) and the three months after the minimum wage hike (June, July, and August),⁶ while o^I and i^I denote outflows from and inflows into the informal sector employment (e^I), respectively, and in the approximation we impose the steady state condition

⁶In the year 2000 the change in the minimum wage occurred in April. Thus we considered the two periods December–January–February, and May–June–July.

$$\Delta e_t^I = i^I - o^I = 0.$$

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 Table 5 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 effect in some years (e.g. 2000) is negative.

5. FINAL REMARKS

The 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 additional 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 characterize the type of sorting that is expected to occur after a minimum wage hike. Finally, we went back to the data to test the key implications of the model and measured the importance played by sorting in wage variation in the informal sector after a minimum wage hike. We found that the skill composition of outflows from the informal sector to the formal sector and vice versa after the policy change are broadly in line with the implications of the model. We also found evidence that the shadow sector declines and educational attainments in both sectors increase in the aftermath of a minimum wage hike. This evidence is consistent with the sorting hypothesis while it is not with the standard theory reviewed in Section 2, predicting a positive labor supply shock in the informal sector. Finally we decomposed the total variation of average wages in the informal sector between the lighthouse and the sorting components, finding that the latter 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 at 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 analyze in more 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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