An Empirical Model of Shadow Markets, the Minimum Wage, and Mandated Non-wage Benefits

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21st September 2004

Abstract

This paper develops a model of workers choosing employment in the formal or informal economy, where formality is defined as abiding by the minimum wage and participating in a set of payroll taxes and non-wage benefits. Enforcement of a minimum wage creates a kink in the trade-off between wages and benefits, causing workers to clump at the minimum wage. The maximum likelihood estimation makes use of identifying information from the wage distribution and the plentiful cross-sectional information to generate precise estimates even in the presence of a fairly short time-series. Estimating the model on Brazilian data recovers preferences for work, non-wage benefits, and a two-parameter "evasion cost" that reflects enforcement and reveals the wage penalty of working in the informal sector. The estimates reveal that the minimum wage in Brazil does not increase unemployment, rather it raises informality. Informal behavior is complementary, so that violating the minimum wage encourages agents to violate other laws. This complementarity can be substantial among the poorly educated. Labor market regulation and enforcement depresses wages among the low-skilled and increases wage inequality. Informal work carries a wage penalty of 23% of salary.

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1 Introduction

Labor market regulation is ubiquitous, though its enforcement is not. Many countries legislate a worker's paradise of mandated minimum benefits and remuneration but do not fully enforce the regulations, allowing the growth of large unregulated shadow economies in the labor force. On the margin, once a given worker finds it impossible to find fully legal employment, there may be a strong incentive to ignore other cumbersome labor regulation. A worker earning less than the minimum wage may find that, given their illegal state, it is very low-cost to evade payroll taxes and convert the payments to higher wages. Legal compliance is then a complementary good that is of less value done partially.

This paper uses a large dataset from Brazil to measure the costs to workers of being in the shadow economy and estimate the degree to which initial movement into informality encourages further noncompliance. It also estimates how the minimum wage and mandated non-wage benefits change the size of the shadow economy, labor force participation, wages, and wage inequality. The estimation accounts for the selection of workers into and out of the work force and the endogenous choice of worker benefits and legality.

Methodologically, this paper presents a way to recover minimum wage estimates that relies principally on cross-section, not time-series, information. Many developing countries have cross-sectional surveys that do not extend back very far in time. The time series is often so short that the assumptions required to identify minimum wage effects may be unpalatable. Furthermore, measurement error in the price index may create large biases in countries with high levels of inflation. This paper presents an alternative method for estimating labor market distortions, given many observations but not much detail and a relatively short time series.

The model allows workers to trade benefits for wages, providing an alternative to unemployment for low wage workers. This trade-off creates a mass point of workers at the minimum wage which is in line with what one observes empirically. Thus, even in developed countries, if non-wage benefits can vary, minimum wages distortions may not occur in employment, but in explicit and implicit non-wage benefits. The empirical model also estimates a distribution of preferences for non-wage benefits relative to cash compensation.

The estimation and accompanying simulation indicate that:

1. Formal workers receive a wage premium of 23% on average, controlling for their higher productivity.

2. Enforcement of the minimum wage is incomplete, but there are still substantial costs to informality. These costs rise strongly with education.

3. Mandated non-wage benefits and the minimum wage law do not have strong effects on labor force participation among Brazilian men, although they do *increase* wage inequality and depress wages among informal workers.

4. Most workers value the mandated benefits package at less than its cost, which is not surprising as some benefit payments are only tenuously linked to the benefit they are to provide.

5. Lower minimum wages encourage workers to formalize their benefits: a 10% decrease in the minimum wage *increases* by 1.9% the number of workers paying all payroll taxes. Among some illiterate workers the increase is 9%, implying strong complementarities across types of informality.

Previous Research

This paper brings together work on informal or shadow economies, minimum wages, non-wage benefits and legal compliance. On the theoretical side, Rauch (1991) and Agenor & Aizenman (1999) develop models of how minimum wage changes affect movements between sectors.[1] These models predict that rising minimum wages decrease the size of the formal sector and not only do formal sector wages rise under a minimum wage, informal sector wages may fall. The second result, market segmentation, is a common outcome of 'insider/outsider' models.

Maloney (2001) and de Soto (1989) present the informal market as an entrepreneurial haven from excessive government regulation, albeit an anarchic haven where contracts and property rights are difficult to enforce. Telles (1993) and Sedlacek and Paes de Barros (1990) note that Brazil's informal sector workers are not necessarily low-wage earners and that there is a great deal of mobility between sectors.

Shadow economies have an extensive literature recently reviewed in Schneider & Enste (2000), but there is little empirical evidence on how labor market regulation specifically affects informality. Using cross-country evidence, Loayza (1997) finds that an index of labor regulation is correlated with larger informal sectors. Saavedra & Chong (1999) estimate the costs of informality in Peru allowing for the endogeneity of informality. They find that the coefficient on education in a wage equation is higher among formal workers. Unfortunately, their definition of informality does not include minimum wage violations, making direct comparisons difficult.

Jones (1997) uses aggregate data in Ghana on the formal and informal sector and finds that informal employment rose 1.3% when the public sector minimum wage rose 10% relative to the manufacturing wage. Suryahadi et al. (2003) find that the minimum wage dampens formal employment in Indonesia using state-year observations over 12 years.[2] In Trinidad, Strobl & Walsh (2003) use the imposition of a national minimum wage to asses the degree

[1] Edwards and Edwards (2002) develop a similar model based on the decision to pay or evade social security taxes. Squire and Suthiwart-Narueput (1997) develop a model of labor market regulation which focuses on the importance of compliance in any discussion of minimum wage or regulatory policy.

[2] Arrowsmith et al. (2003) provide anecdotal evidence from interviews of 55 small British firms faced with a national minimum wage. Though they do not provide formal estimates of minimum wage effects, they conclude that partially or fully evading the law was an important response to the new regulation.

of legal compliance. They have longitudinal firm data that lets them track how firms changed wages before and after the change. They find that about one third of firms failed to comply with the new law, and that compliance was positively correlated with firm size. Bell (1997) looks at minimum wage changes in Mexico and Columbia using formal sector firm data and time-series variations for identification. She finds unemployment effects among low-skilled formal workers in Columbia but not Mexico, where the minimum wage is farther left in the wage distribution and so is less binding.

In Brazil, Foguel et. al (2001) estimate minimum wage effects on the formal and informal sectors using an aggregate time–series model. They find that the minimum wage contributes slightly to informal sector employment but mostly causes very small employment losses in the formal sector. The employment elasticity in the formal sector was around -0.01 with the informal effect a tenth of that. Fajnzylber (2001) follows workers using one-year panel data and estimates minimum wage effects that are allowed to vary by the lagged wage, which is treated as exogenous. This approach shows significant wage effects for the minimum wage and small but negative employment effects, although the employment effects can be quite high among informal, low-wage workers. Lemos (2002) provides both an overview of past literature on minimum wage work in Brazil and estimates a variety of effects based on year and state variation in the size of the spike at the minimum wage.

The empirical descriptive literature on minimum wages in developing countries documents clumps in the wage distribution at the minimum wage, which can occur in both the formal and informal markets (Neri et. al (2001), Jones (1997), Maloney & Nunez (2001)). Thus the minimum wage effect may not be limited to workers earning close to the minimum wage in the formal sector, but can cause clumping for workers in the informal sector. A theory of the minimum wage should be able to explain why workers appear to be clumping at the minimum wage, and an empirical model ideally should reproduce this result.

The minimum wage specifically has excited a great deal of research in the U.S., primarily focused on its effects on employment and wages (particularly teen wages). A summary can be found in Brown (1999). Of particular note is the work by Lee (1999), which finds that the minimum wage decreases wage inequality, a result that does not hold here.[3] Flinn (2002) develops a search model for the United States capable of generating a clump at the minimum wage as well as spillover effects to higher wages. The model as presented is focused on the United States, and so does not deal with incomplete compliance, but does illustrate the advantages of developing an empirical minimum wage model grounded in economic theory.

There is also a U.S. literature on how a minimum wage affects non-wage benefits. This literature is focused on non-mandatory benefits, but still provides a comparison with the tradeoffs presented in this paper. The premise, laid out in Rosen (1972), is that in the face of a binding minimum wage a firm reduces compensation by reducing non-wage benefits. Studies such as Acemoglu & Pischke (1999), Fairris & Pedace (2004), and Neumark & Wascher (2001) have focused on on-the-job training as an observable example of non-wage benefits. This is unfortunate because one may be concerned that on-the-job training can be a means for the firm to raise the worker's productivity up to the minimum wage, and not just a non-wage benefit. These studies rely on time-series variation in state and federal minimum wages, which may not be sufficient to identify the effects. While Neumark & Wascher (2001) find a reduction in training from the minimum wage, the other two find no relationship. More relevant, perhaps, is the work by Simon & Kaestner (2003) on how the minimum wage affects health insurance, pension coverage, and other non-wage benefits. Using time-series variation in state and federal minimum wages, Simon & Kaestner (2003) conclude that there is no discernible relationship between higher minimum wages and fewer fringe benefits for the low-skilled based on a comparison between high and low skilled workers.

[3] In fully compliant regimes, the informal sector wage is driven to zero through full disemployment. This makes the *observed worker* wage distribution look less unequal as the minimum wage rises. Thus in developed countries, economists have focused on measuring employment losses instead of wage dispersion. In a developing economy, it is not clear which effect is more important.

The model presented and tested here jointly models wage and non-wage compensation in a regime with imperfect enforcement. Wages and benefits are endogenous outcomes of the model. The estimation recovers the parameters of an evasion function that parameterizes the costs of illegality. It also recovers a distribution of preferences for the legal package of non-wage benefits. The estimates are recovered off cross-sectional variation rather than time-series variation. This allows one to take advantage of large cross sections as opposed to short time-series and may be a fruitful alternative when time-series methods are hindered by lack of variation, insufficient length, or confounding macroeconomic effects.

Section 2 describes the institutional setting for the estimation. Section 3 presents the model. Section 4 describes the data used and Section 5 gives results from the estimation. Section 7 simulates the effects of minimum wage changes and checks the fit of the estimates to the observed data. Section 8 concludes.

2 Institutional Setting

This section provides background on the labor market regulations of interest in Brazil and their enforcement. It then provides evidence on the size of the shadow economy in Brazil.

2.1 Labor Market Regulations

Brazil's labor regulations are extensive. The first section focuses on the size and nature of payroll taxes and how they benefit the worker. The next section examines the minimum wage and the last section discusses enforcement.

2.1.1 Payroll Taxation

As shown in Table 1, Brazil has several large, mandated non-wage benefits, some of which the worker may fully value and others of which are only partially valued compared to their cost.[4]

The taxes and benefits are all paid proportional to the worker's wage. When aggregated, they approximately double the cost of labor employment. Note that some benefits have a cost that is multiplied by the wage plus other benefits. This compounding is what brings the total costs from 176% of the wage to double the wage.[5] Analyses based solely on the observed wage could be very misleading if these benefits are paid only by some workers. With imperfect enforcement workers will have an incentive to move partially valued benefits into fully valued wages so as to equate the marginal benefits of types of compensation.

Table 1: Labor Costs in Brazil

Benefit	Cost as fraction of wage
Annual Bonus	0.08
Personal Unemployment Fund (FGTS)	0.08
Other Direct Payments and Subsidies	0.22
Paid Leisure	0.12
Social Security, accident insurance and worker training programs	0.26

Payments post-1988
Source: Table 7.1 in Amadeo and Camargo (1997)

The mandated annual bonus and individual worker unemployment fund are

[4]See Amadeo and Camargo (1997) for a careful summary. Note that in the model in this paper, benefits will be treated as a continuous variable ranging from full to nothing. This is a straightforward simplification of the process in which an agent values some benefits as much as cash, others partially, and others not at all. The model treats these as a composite "benefits" good, where the specific benefits and their amounts are not modeled. This captures the agent's desire to take some amount of compensation in benefits, but often less than the legal amount; which is the basis for regulation evasion.

[5]The same source for the table notes payroll benefits across several countries, and Brazil is comparable to many other countries in its payroll taxes.

both redeemable as cash at some point in the future, thus their value depends on the agent's time-preference and credit constraints. On the other hand, there are many taxes that fund government programs such as social security, accident insurance, or worker education programs. The benefits of these taxes are only tenuously linked to the individual paying them and so some workers may be very willing to ditch these benefits in exchange for a higher wage. Their willingness to pay for such benefits may reflect a preference for legality or honesty itself, rather than any clear cash benefit realized by the agent.

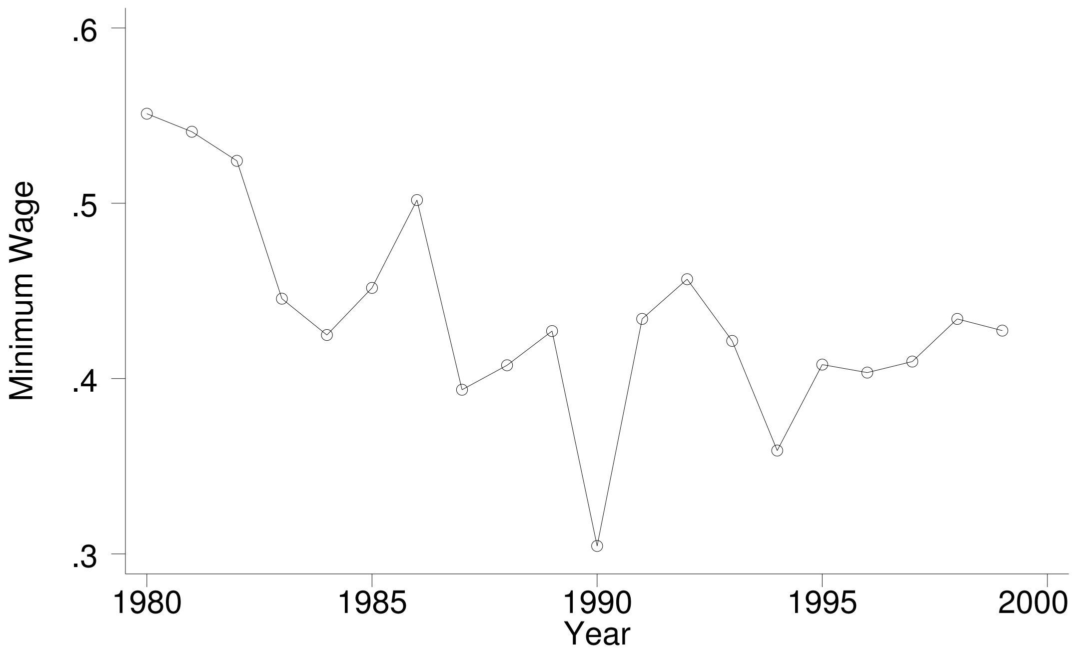
2.1.2 Minimum Wages

Figure 1 graphs the hourly minimum wage in constant Reals during the sample period of 1981-1999. To get real values under high inflation is always problematic. In this case, the minimum wage is deflated using the national numbers of the most widely used consumer price index in Brazil, the *IPCA*. The index is designed to be broadly representative of consumption across a wide range of consumers, from those at the minimum wage to those making ten times as much. The base year here and throughout this paper is 1994, when the Real was instituted as the currency unit. This is particularly convenient as a reference point because its value at that time was one U.S. dollar.[6]

The Brazilian minimum wage is set at the federal level by the executive branch with oversight by the legislature and is always denominated in nominal terms. When inflation is low, it is set annually in May. In times of high inflation, it is adjusted more frequently. In the early 90's, a period of very high inflation, it was updated each month in order to preserve its real value. The minimum wage is uniform across the country so that from 1984 to 1999 its nominal value was exactly the same throughout Brazil.

[6] In the first three years of the sample the minimum wage for the South was slightly higher than the North, which is accounted for in the data used. This paper uses a single, national, deflater. The estimation is robust to fixed regional price differences as prices are estimated separately by region.

Figure 1: Minimum Wage in Brazil, 1981-1999



2.1.3 Enforcement

The Secretaria de Inspe*ção* do Trabalho within the Brazilian labor ministry employs thousands of inspectors charged with ensuring compliance of *all* labor laws, from payroll to health codes (Minestério do Trabalho, 1979). Across the 1990's 3,285 inspectors were employed in 1990 but only 1,960 in 1995. Even though the number of inspectors stabilized in the late 90's to about 2,400 , the number of businesses and employees, inspected fluctuates 20-30% from year to year. The ministry records indicate that between 15 and 20 million workers' businesses are inspected in any given year (Minesterio do Trabalho e Emprego, (2000)).

It is not at all clear, though, how much attention is paid to enforcing the various parts of the extensive labor code. Recent inspection effort has been focused on stamping out slave and child labor, as opposed to minimum wage or payroll violations. Anecdotal evidence suggests that actual enforcement of these laws is often by wronged workers complaining to the Brazilian labor courts. The labor ministry reports that non-wage benefits and minimum wage violations are prosecuted in roughly the same amounts; in 2001, the inspectors found 11,970 businesses in violation of the minimum wage law, 14,726 in violation for having unregistered workers, and 16,030 for failure to pay FGTS, the unemployment fund benefit (Minesterio do Trabalho e Emprego, (2002)). These numbers are suggestive that for non-wage benefits and the minimum wage, enforcement efforts are of comparable magnitude.

Firms in violation can be assessed up to 24 months of back-paid wages and benefits. and a fine that can be 3 to 120 times the value of the monthly minimum wage. Violation reports have a statute of limitations of two years (*Consolidação das Leis Trabalhistas*, 1943; Brazil Legal Code 1989, 1999).

Of course, what the law says and what actually occurs may be two different things. Ideally one would like detailed information about fines actually paid and their frequency. Even then, many of the costs of evasion may actually revolve around unobserved bribery of officials. Although this information is not readily available, the estimation does not rely upon explicitly observing the costs of evasion, but infers those costs from the wages of workers.

2.2 The Shadow Economy

Measurement of informal activity is fraught with difficulty. Agents engaged in illegal activity are often less than forthcoming about their status. Labor laws in a country like Brazil can provide useful data on this point for several reasons. First, labor laws inflict punishments on firms, not workers; so the worker has far less concern about how information about a survey might be used against them, because it is the employer who faces penalties.[7] Second,

[7] This is not to say that the worker might not have some incentive to lie if the worker believed that the information a) would be used against the employer and b) the worker would lose their job on account of this. I am unaware of any evidence that the ministry overseeing labor regulations attempts to coerce this type of information from the Census Bureau. This would involve a remarkable amount of coordination across government bureaucracies.

although some attempts are made to enforce labor laws, they are widely violated, thus enforcement is low enough to make reporting feasible but the law may still be having an effect on the economy. Third, the labor market is the subject of regular surveys across many workers, admitting a large sample of data with which to approach the question. This section briefly looks at summary statistics for Brazil's economy and then makes precise the definition employed for informality.

2.2.1 Informality observed in the data

Table 2 summarizes market informality and structure across the North and South of Brazil in 1999.[8] The North is a poor but densely populated region with 15 million men between the age of 15 and 55. The median wage, R$0.57, is less than half the South's median wage, R$1.21.

One measure of informality is the number of workers below the minimum wage. The federal minimum wage hits much higher up in the North's wage distribution, as seen in the worker statistics on "% Working at the Minimum Wage" and "% Working below Minimum Wage."[9] In the North, 38% are at or below the minimum wage while only 11% are at or below the minimum in the South.

Table 1 also reports on worker registration and payment of social security taxes. Employees are legally required to pay social security taxes, be registered with a signed work contract, and be paid at least the minimum wage. Payment of these taxes is mandatory but only one third of employees report paying in the North, while about three-fifths pay in the South. This failure to pay social security taxes is a particular concern in many countries that,

[8]Throughout the paper, "North" refers to all the states in the North and Northeast census regions. "South" refers to all the states in the South and Southeast census regions. The comparatively small Center-West region is excluded from the analysis. The data and sample restrictions are the same as described in Section 4, except this sample is not restricted to 100,000 observations.

[9]See Section 4 for a definition of "at" the minimum wage—it includes all workers within a tight window around the statutory minimum.

Table 2: Brazilian Men, Age 15-55

Statistic	North	South
Population (millions)	14.6	27.8
% Working	68%	74%
Median Years of Schooling	5	7
Median Age	29	32
Median Wage (1994 Reais)	R$ 0.57	R$ 1.21
% Paying Social Security	32%	61%
% Registered Workers	43%	68%
% Working at Minimum Wage	11%	4%
% Working Below Minimum Wage	27%	7%

like Brazil, legislate generous social security payouts but witness widespread payroll tax evasion.

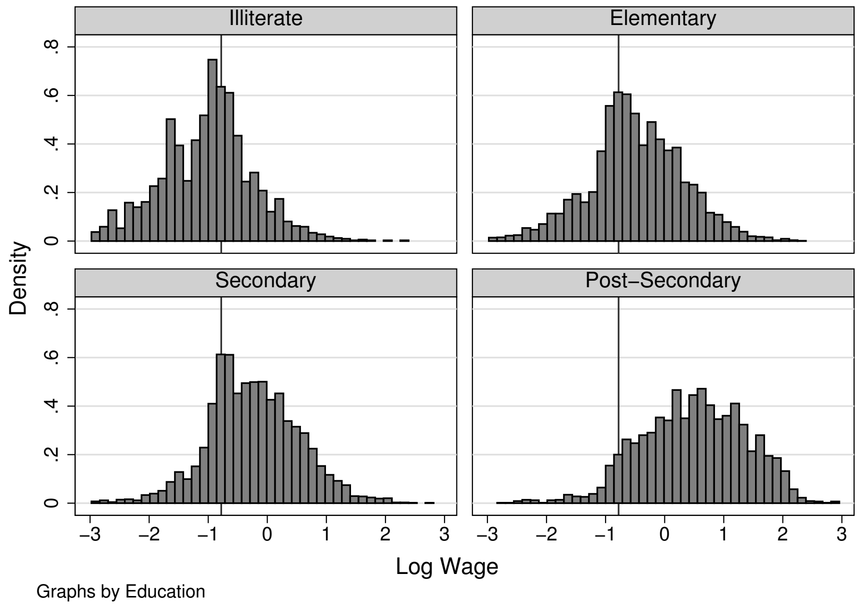
Unregistered work is also an excellent indicator of informality. Only 43% of workers are registered in the North, indicating it may be easier to evade the law there. In the South, 68% of workers are registered.

Table 2 makes clear that informality is widespread in Brazil, but that it varies geographically. The informal area is also the poorest. This makes it difficult to say *a priori*, which part of Brazil will be most affected by the minimum wage. In a fully compliant regime, the minimum wage would have its strongest effect in the low–wage North, but the North appears to be *far less* compliant than the South. Hence it is an empirical question to determine if the minimum wage has more impact in the lower–wage North or in the more compliant South.

Similarly, enforcement may vary across job markets. If regulations are enforced only among white collar or skilled labor, then one should look for labor market effects among the educated, as opposed to the more obvious low-skilled market with its low wages. Figure 2 shows wage histograms for

1992 in Brazil across four mutually exclusive and exhaustive education categories.[10] The 1992 log minimum wage of -0.78 is marked on each graph. One productive way to look at these graphs is as a progression showing how shifting the mean of a wage distribution causes differing kinds of minimum wage distortion.

Figure 2: Log Wage Distributions by Education Level, 1992



There is a clear tendency for wages to clump near the minimum, but among the well-educated this effect is hard to pick up. It also may be the case that the left tail of these distributions seem to have fewer workers than one might expect. If these absent workers have traded off benefits in order to increase their observed wage, then they are present as payroll evaders working above the minimum wage. Otherwise they are unemployed.

The histograms reveal just how frequent minimum wage violation is, espe-

[10]The categories are illiterate workers, workers with up to the elementary school degree attained at 4 years of schooling, those with up to a secondary schooling degree attained at 8 years of schooling, and those with more schooling.

cially among the illiterate. Possibly labor law evasion is so easy among these groups that the law is irrelevant to them, or relevant to only a small subset. On the other hand, even among the least educated, there is what looks like a clumping of workers at the minimum wage. The clumping suggests that the minimum wage is doing *something* although it does not reveal what exactly that something is. Given the possible differences in their labor markets, it is important to allow for evasion costs that vary across different educational groups.

Eyeballing wage distributions is informative but does not unravel the underlying economic processes. The graphs *do not* reveal: how workers trade off benefits and wages in response to the minimum wage impetus, whether agents who should be working below the minimum wage are not working or whether they have moved up in the distribution, and to what extent the wage informal workers receive is affected by the fact that they must work illegally. Thus Section 3 presents an economic model that can be estimated to answer these questions.

2.2.2 Defining Informality

Given the regulations in existence, the informality of a given worker's employment can vary greatly. Some agents pay payroll taxes but receive less than the minimum wage. Others avoid the payroll taxes and government registration requirements but are above the minimum wage. Thus in this paper, a formal worker is one paid at least the minimum wage, registered with the government, and for whom all payroll taxes are paid. Empirically, observed payment of social security taxes and work registration are proxies for payment of all payroll taxes and non-wage benefits. This assumes that social security taxes are the first benefits workers relinquish when abandoning non-wage benefits or that workers who are registered with the government receive the mandated benefits package, neither of which is likely to be a bad assumption.

3 Model

This section presents an empirically estimable model of a labor market with both compliant and noncompliant workers. From the available data, one observes whether or not each agent chooses to work and, for workers, both the wage and whether or not they receive the full set of mandated benefits. Based on these observed characteristics, each agent is in one of five observable states, which form the basic divisions for estimation:

A Formal Workers

B Workers that are informal due to violating just the laws regarding non-wage benefits

C Workers that are informal due to violating just the minimum wage law

D Workers that are informal due to violating both the non-wage benefits laws and the minimum wage law

E Not Working

These states are mutually exclusive and exhaustive. The formal sector is defined as those that are in compliance with all the labor laws. The informal sector is multidimensional, allowing two different types of legal violation: noncompliance with mandated benefits laws and noncompliance with the minimum wage. Workers may choose to comply with one or neither of these laws, thus the informal market is subdivided into states B, C, and D above. Given a model of how agents choose between these states, one can estimate the complementarities across types of informality.

The model has two kinds of actors: individuals and firms. Firms compensate workers with a package of wages w_i and a multiplicative benefits rate τ_i, so that total compensation paid is $w_i\tau_i$. Benefits have a legally mandated rate, B. Wages are required by law to be at least the minimum wage, M. Firms have the option of ignoring the minimum wage and/or benefits when paying workers. Doing so incurs a worker-specific evasion cost, Δ_i, that, in equilibrium, firms can pass back to the worker. Firms present each worker with a wage schedule $w_i(\tau_i)$ that maps out wage/benefit packages across which the firm is indifferent.

An individual is defined by four values:

1. productivity, t_i;
2. δ_i, capturing individual variation in evasion costs;
3. individual preferences for work, ζ_i;
4. a preference for non-wage benefits, θ_i.

The individual maximizes over consumption and leisure given a standard budget constraint and the ability to convert non-wage benefits into consumption (captured by the non-wage benefit preference, θ_i). Each worker is further constrained by his personal market wage schedule, $w_i(\tau_i)$, as he chooses the optimal combination of wages and benefits to maximize consumption.

An agent chooses his state based on his productivity level, individual evasion cost, and preferences over work, wages, and non-wage benefits. By estimating the parameters of the model, one can determine how agents react to changing regulation and enforcement, and the extent to which stiffening one law can discourage compliance for *other* laws.

The following sections discusses the choices faced by firms (3.1), the specification of the evasion cost function (3.2) and the resulting utility maximization problem solved by individuals (3.3). The section ends with some comparative statics resulting from the model (3.4).

3.1 Firms

Firms each have access to the same production technology which takes labor as its only input. All firms produce the same consumption good and there is no capital. The cost of a worker depends on their desired mix of benefits and wages, as well as the costs of evading the law for informal workers. These factors affect the observed wage paid to the worker. Thus firms maximize:

$$\Pi = y(T) - \sum_{i=1}^{N} \pi_i t_i \tau_i \Delta_i \tag{1}$$

where $y(T)$ is the production function, $T = \sum_{i=1}^{N} t_i$, N is the number of employees at the firm, t_i is the productivity of agent i, and π_i is the "piece rate" price of a unit of productivity from worker i. τ_i is a multiplier on the wage covering the costs of non-wage benefits which, to be legal, are required to be at the level B. Δ_i is the costs paid for evading the law for worker i and is weakly decreasing in both $w_i < M$ and $\tau_i < B$. $\Delta_i = 1$ for all formal agents, who are those with $w_i \geq M$ and $\tau_i = B$. For informal agents, $\Delta_i > 1$ and is discussed in Section 3.2.

The total payroll cost is a function of productivity, benefits, evasion costs, and an equilibrium price π_i, discussed below, which ensures the cost of a unit of productivity is the same across workers. Workers receive a wage $w_i = \pi_i t_i$. The multiplicative form for costs needn't be restrictive. Benefits, which are discussed in Section 2.1.1 and Table 1, are proportional to the wage, and Δ_i can be a function of all the other variables, thus one can entertain any form of evasion cost one wishes. Given this evasion cost, consider how π_i is determined for formal and informal workers

Formal Sector Prices For formal sector workers benefits are at B and there is no evasion cost ($\Delta_i = 1$). Since these values are constant, the price will also be constant, so that one can write the cost of employing a formal worker as $\pi_F t_i B$ with $w_i = \pi_F t_i$, where π_F is the piece-rate price for formal sector work.

Informal Sector Prices Given a formal sector price of π_F, there are some workers for whom $\pi_F t_i$ is less than the minimum wage, M, which makes it illegal to hire them at the going formal price π_F. Coupled with workers who prefer cash to the mandated benefits level B, these workers form an informal market of workers interested in evading the law. Firms face an extra evasion cost per informal worker but do not have to pay the same formal sector price π_F for labor. They may also pay fewer benefits which are substituted for higher wages. Define cost per worker as

$$C_i \equiv \pi_i \cdot t_i \cdot \tau_i \cdot \Delta_i. \tag{2}$$

The price π_i will be a function of the evasion cost Δ_i, which is itself a function of benefits and wages, and τ_i.

Equilibrium in the market requires that informal workers offer their work at a price per unit of productivity that makes them competitive with formal workers. The price schedule must be such that the per unit cost of productivity is the same for all agents:

$$\frac{C_i}{t_i} = \frac{C_j}{t_j} \quad \forall i, j \tag{3}$$

Note that for any given worker, t_i cannot be incremented marginally. Thus the firm does not increment t_i but rather picks among the discrete choices for the best deal available. The firm compares average cost of all the possible marginal workers it can hire. As noted above, for all legal workers the price schedule is a fixed constant, $\pi_i = \pi_F$. More generally, the market price schedule π_i, requires undoing the added costs of evasion and the extra wages paid in exchange for foregone benefits. Thus

$$\pi_i(\pi_F, \Delta_i, \frac{B}{\tau_i}) = \pi_F \cdot \frac{B}{\tau_i} \cdot \Delta_i^{-1} \tag{4}$$

ensures that both (2) and (3) hold for all workers. This price function has the firms exactly passing on their evasion costs to workers. This is as one would expect as long as the firms have the option of hiring a formal worker with no evasion cost. Observed wages,

$$w_i = \pi_F \cdot t_i \cdot \frac{B}{\tau_i} \cdot \Delta_i^{-1}, \tag{5}$$

are a combination of the evasion cost, productivity, and the extent (if any) to which the worker substitutes wages for benefits. Since Δ_i depends on the wage and benefits package, w_i is only implicitly defined by (5).

Thus firms are willing to hire workers that are formal or informal, and the informality of the worker can be in either wages, benefits, or both.

3.2 Evasion Costs

The key to understanding the effects of regulation under incomplete enforcement is to understand the costs associated with evading the law. Section 3.2.1 considers the how an evasion cost in general might affect a worker's decisions to take benefits. Section 3.2.2 then specifies a log-linear form for evasion costs and discusses its properties.

3.2.1 General Results

Before assuming a more specific form for the evasion cost, consider one general implication of the model. Agents are faced with a wage schedule in (5) where wages are a function of benefits, $w_i = w_i(\tau_i)$. Agents interested in trading off benefits for higher wages then face the following marginal tradeoff at differentiable points:

$$\frac{d\ln(w)}{d\ln(\tau)} = -\frac{1+\Delta_\tau}{1+\Delta_w} \tag{6}$$

Where i subscripts are suppressed and the τ and w subscripts indicate elasticities of Δ to the subscripted variable. This elasticity between wages and benefits, derived from taking total derivatives of the log of (5), maps out a budget constraint for the movements between the differentiable points of benefits and wages. Changes in the wage above the minimum are assumed to not affect evasion costs, so that $\Delta_w = 0$ for all wages above the minimum, and:

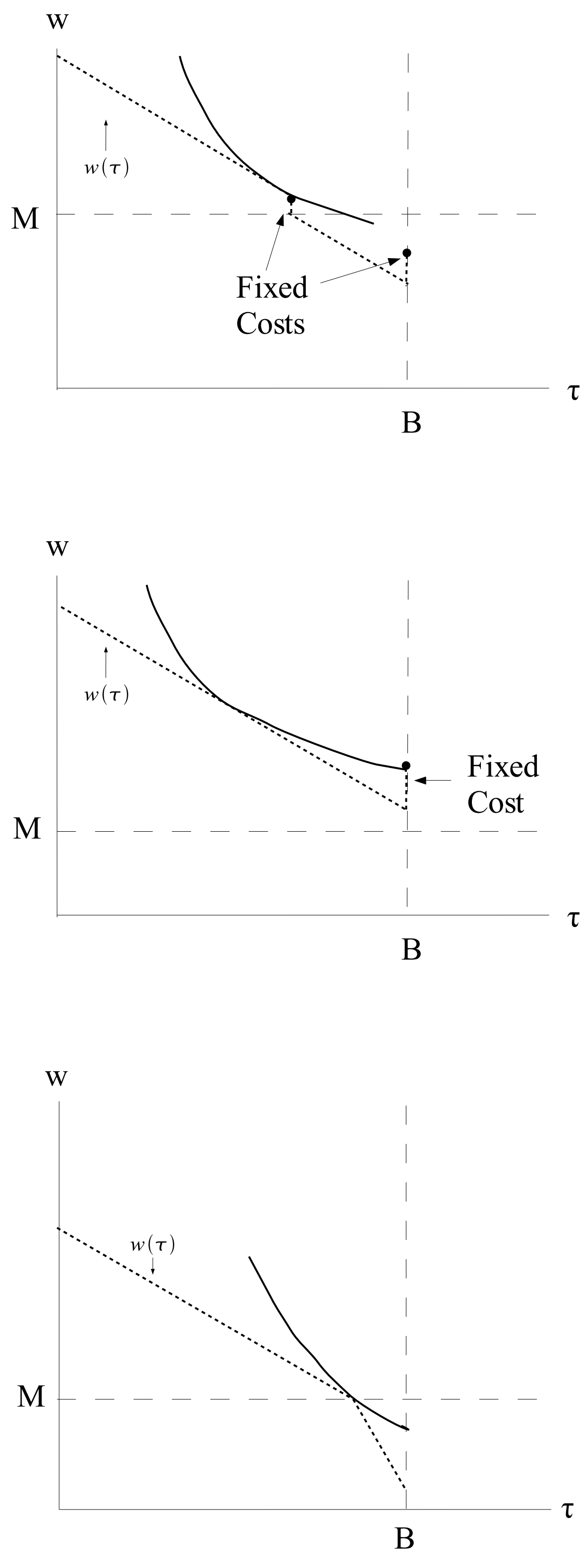
$$\frac{d\ln(w)}{d\ln(\tau)} = -(1+\Delta_\tau) \quad w \geq M. \tag{7}$$

There are two potential issues as the wage approaches the minimum wage, M, or the full benefits level, B. The first is fixed costs of illegality, so that there is some cost paid for any illegality, even if the worker is close to the legal levels. If there is a fixed evasion cost such that $\lim_{w\uparrow M}\Delta \neq 0$ or $\lim_{\tau\uparrow B}\Delta \neq 0$, then there will be an upward jump in the budget constraint at the minimum wage or full benefits level. Either of these cause some workers to stay legal in one or both dimensions in order to evade the fixed costs. If the fixed cost in minimum wage violation is dominant, then one would expect many workers to dump benefits in order to get to the minimum wage. If the loss of benefits is more important then workers will tend to stay with full benefits even though they are otherwise illegal. This situation is graphed in the top panel of Figure 3, with a representative wage schedule, $w(\tau)$, and, for the sake of illustration, a potential indifference curve a worker might have across wages and benefits. Note how the fixed costs create a "dead zone" of wage and benefit combinations (those where the agent is jointly illegal in both spaces) that few agents would find optimal.

One simplification is to assume that fixed costs are paid only once for any evasion. Then a worker with $w(B) < M$ always pays them, but a worker with $w(B) > M$ only pays fixed costs if he chooses to drop benefits, thereby becoming informal. This situation is graphed in the middle panel of Figure (3). This type of market distortion causes skilled workers to favor benefits to avoid fixed evasion costs, while those below the minimum wage don't face this fixed penalty as they are already illegal. Thus fewer low-skilled workers clump at full benefits. A larger number of skilled workers clump at full benefits, not because they value them fully, but rather to avoid the costs of informality.

Aside from fixed costs there may be distortions due to kinks in $w(\tau)$. This situation is graphed in the last panel of Figure (3) assuming no fixed costs. Since B is the highest level of benefits, kinks in Δ_τ at B are not interesting. On the other hand, if $\lim_{w\uparrow M}\Delta_w \neq 0$ when $\tau < B$, then agents face a kink in the trade-off between benefits and wages at the minimum wage, since $\Delta_w = 0$ for $w > M$. The kink is the result of the change in the trade-off

Figure 3: Example Trade-off Between Wages and Benefits



between benefits and wages and creates a group of workers who stay at the minimum wage as their maximum utility point.[11]

3.2.2 Log-linear Specification

Firms face fines for employing informal workers, but only if caught. The fine consists of two parts, an idiosyncratic fine set by the trial judge ranging from 3 to 120 times the minimum wage and up to 24 months of back-paid wages and benefits. Thus any functional form employed should allow for a possible fixed cost fine and a payment that varies with how far out of compliance the worker is.

Empirically, there is a sharp decline in the number of workers taking full benefits as one moves below the minimum wage. This suggests that there are substantial complementarities in evasion. It also *does not* fit a model with separate strong fixed costs for wage and benefit compliance, because in that case dropping below the minimum wage would not encourage workers to drop benefits as well. Thus a cost function like that modeled in the second panel of Figure 3 , where there is only one fixed cost, is more appropriate.

Although many evasion costs might be entertained, the remainder of the paper focuses on a symmetric, log-linear specification. Symmetry assumes that all evasion costs are treated identically, whether it be in the minimum wage or non-wage benefits. This assumes that enforcement and punishment of minimum wage laws are not substantially different than that of non-wage benefit laws, and where fixed costs of evasion are only paid for the first infraction, not again for each evasion, as discussed above. This log-linear form can be written as:

$$\ln \Delta_i = -D_i \left(\delta_i + \delta_M(\ln(M) - \ln(\min(w, M)) + \delta_M(\ln(B) - \ln(\min(\tau, B))\right) \tag{8}$$

[11]The kink does not actually require that changing wages above the minimum be irrelevant to changing evasion costs, only that there is a discrete, positive change in Δ_w at M.

Where $\delta_i < 0$ is specific to the agent and $\delta_M \in (-1, 0]$. $D_i = 1$ for those with either form of illegality and 0 otherwise. This form sets $\Delta_w = \Delta_\tau \equiv \delta_M$ where δ_M can be thought of as a tax on illegal activity. (8) includes a fixed cost of evasion, δ_i, which is paid when an agent become informal in any way. Thus it admits the possibility of agents clustering at full benefits in order to avoid the evasion cost δ_i and allows individual heterogeneity in evasion costs by making the fixed cost parameter δ_i agent specific.[12] The slope parameter δ_M allows for kinks at the minimum wage in $w(\tau)$.

Thus (8) produces wage schedules like those illustrated in the second and third panels of Figure 3, though not the first panel which has separate fixed costs for the different kinds of evasion. As noted above, the observed complementarity between benefit and wage evasion suggests that fixed costs do share a large common component. (8)'s symmetry and log-linearity is somewhat restrictive; but the restrictions make estimation easier and could be relaxed depending on the available data.

The form chosen conveys the institutional details noted above. Namely, there are fixed costs associated with illegality and, due to back pay provisions, costs rise with increasing illegality. Minimum wage laws and non-wage benefit violations are enforced and punished by the same agency and in the same courts, with similar fines imposed for either type of violation. Thus imposing a symmetric cost structure is reasonable.[13] The cost imposed by the fines is tempered by the fact that getting caught is not a certainty, but a probabilistic event and so must be weighted accordingly.

A more complete model of evasion would consider the probability of getting caught, recognizing that workers can turn firms in. (8) is a reduced form

[12]Evasion costs are not correlated across workers, thus firm size does not affect the need to hire formal or informal workers. One could easily modify the model to have correlated evasion across workers, so that all workers are caught at once. Then firm size would be incorporated into the model as a component of evasion costs, with large firms typically formal. Since firm size is not observed in the available data, these effects would be captured through some random, unobserved component. This model allows for such randomness through δ_i.

[13]If there are important variations in the evasion costs across types of illegality, the estimation will attempt to capture a common cost parameter that maximizes the observed likelihood. The parameter will not be correct but may be close enough to remain useful.

log-linear approximation to this more complete model. It does, however, allow for the possibility that agents with more backpay on the line are more likely to default, since costs rise for those farther from the mandated levels. Further, by allowing for individual heterogeneity in costs, through the fixed cost δ_i, it can capture some of the differences across agents in willingness to turn the firm in. To the extent that such heterogeneity is correlated with observable characteristics, the evasion cost can also vary across these characteristics, allowing for further reduced form differences.

The evasion cost function contains a fixed cost δ_i and a slope parameter that disappears when wages rise above the minimum wage. These features create corner solutions in the resulting wage schedule. Suppress i subscripts and substitute the definition of Δ into the wage schedule (5) to get the following wage function:

$$\begin{aligned} \ln(w) &= \ln(\pi_F t) + D\delta + (1+\delta_M)\cdot\ln\left(\frac{B}{\tau}\right) && w \geq M \\ &= \frac{\ln(\pi_F t)+\delta+\delta_M \ln M}{(1+\delta_M)} + \ln\left(\frac{B}{\tau}\right) && w < M \end{aligned} \tag{9}$$

The formal and informal markets function as one labor market with one price constant π_F that is adjusted when hiring an informal worker. The adjustment has two parts: there is a wage discount determined by the cost of evasion and a wage increase based on the benefits level chosen by informal workers. The observed wage is obviously a function of the benefits chosen, this is addressed in the decision of the individual. The above equation establishes the payment schedule offered by the firm.

Note that agents working at less than the minimum wage can freely move between benefits and wages at a one-to-one price ratio. This is because they are simply substituting between two kinds of informality—as their benefits fall farther below the mandated level, their wages rise closer to the minimum wage. Since $\Delta_w = \Delta_\tau$, the net change in evasion costs is zero. Those working above the minimum wage who choose to forego benefits face a degraded price ratio of a $1+\delta_M$ percentage wage increase for each percentage point reduction in benefits.[14] This is because dropping benefits raises evasion

[14] Recall that δ_M is always negative and bounded between $(-1, 0]$.

costs by $\Delta_\tau = \delta_M$, but the resulting wage increase does not decrease evasion costs because $\Delta_w = 0$ when $w > M$. Agents must divert a portion δ_M of the proceeds to pay the higher costs of evasion. In economic terms, paying wages in excess of the minimum wage does not give one leeway to violate non-wage benefit laws, thus these agents must pay an evasion tax, δ_M, when moving benefits to wages. This shift in the price ratio results in the kink in the wage schedule at M, which causes workers to clump at the minimum wage.

3.3 Individuals

Individuals only make two choices: whether or not to enter the labor force and a wage/benefit combination. The benefits level determines the wage level according to the wage schedule $w_i(\tau_i)$ found in equation (9) and illustrated in Figure 3. Based on the agent's decisions, the agent then occupies one of the five states discussed previously: formal, informal due to less than full benefits, informal due to working for less than the minimum wage, informal in both benefits and wages, and not working.

Section 3.3.1 models the agent's choices. Section 3.3.2 describes the general utility maximization problem. Section 3.3.3 specifies the benefit preference equation in order to solve the maximization, then Section 3.3.4 maps individual parameters into distinct regions of the parameter space. Lastly, Section 3.3.5 maps these regions of the parameter space into the observable states.

3.3.1 Choices and Preferences

Agent utility is defined over consumption and labor force participation given a set of individual-specific taste-shifters:

$$U(c_i, W_i|\zeta_i, \theta_i) \tag{10}$$

where c_i is consumption and $W_i = 1$ if the agent is employed, 0 otherwise. There is no hours decision, only participation. The taste parameters are defined above. Consumption is produced from wages, benefits, and non-wage income:

$$c_i = n_i + W_i \psi(w_i, \tau_i | \theta_i) \tag{11}$$

where n_i is nonlabor income. The function ψ defines how individuals combine wages and non-wage benefits to produce consumable goods. It is assumed to be increasing and concave in both it's arguments. Figure 3 graphs a "potential indifference curve" between wages and benefits. Those indifference curves each represent wage/benefit combinations that give a fixed value of ψ. The preference parameter θ_i allows this function to vary across individuals. A special case of benefit preferences would be where all workers value the benefits at their cost to the firm. Remembering that benefits are a rate multiplied by the wage, this implies that for that special case $\psi(\cdot) = w_i \tau_i$.

Substitute the consumption constraint, (11), into the utility function, (10), and specify the utility function in logs as $U(\cdot) = \ln(1 + c_i) + W_i \zeta_i$ to get the following concentrated utility function:[15]

$$\ln(1 + n_i + W_i \psi(w_i, \tau_i | \theta_i)) + W_i \zeta_i \tag{12}$$

which workers maximize.

3.3.2 Utility Maximization

The maximization involves two steps. First the agent picks a wage / benefits combination to maximize $\psi(w, \tau)$ subject to the constraint $w(\tau)$ given in equation (9).[16] Given an optimal choice of w^* and τ^*, the agent works if $\ln(1 + n + \psi(w^*, \tau^* | \theta)) + \zeta \geq \ln(1 + n)$.

As should be obvious from Figure 3, the discontinuities in Δ complicate calculation of the optimal wage/benefit package. This section describes the typical first-order tangency conditions and then outlines when the worker is optimally at a tangency, kink, or corner in the wage / benefits space.

[15]The $\ln(1 + x)$ form is used to eliminate zeros in the natural log function.

[16]Individual subscripts are assumed but not printed in the remainder of the section

The wage / benefits problem can be concentrated into an unconstrained maximization of $\psi(w(\tau),\tau)$, which has the following derivative wherever the derivative is defined:

$$w_\tau = -\frac{\psi_\tau}{\psi_w} \tag{13}$$

where subscripts are derivatives and

$$\begin{aligned} w_\tau &= -\tfrac{\tau}{w} & w < M \\ &= -(1+\delta_M)\cdot\tfrac{\tau}{w} & w > M\,,\, \tau < B. \end{aligned} \tag{14}$$

Equation (13) is the standard optimization result that the price ratio, w_τ, is equal to the ratio of marginal benefits. This tangency condition may not be the optimum for two reasons; it may not exist, due to a kink in the wage schedule; or it may be that the worker is better off at the corner $\tau = B$ where the agent is formal and so does not have to pay the fixed cost δ. Consider each case in turn.

Kink in $w(\tau)$ The third panel of Figure 3 graphs the sudden addition of the marginal evasion cost δ_M. This implies there are some values w_τ skips over, so that there is no solution to the previous tangency condition. Workers in such a range desire fewer benefits if the benefits can be traded off at a 1:1 ratio, but are unwilling to discard benefits if there is an evasion "tax" of δ_M. In this case the workers remain at M, forming a clump of minimum wage workers. Naturally this kink only matters if the agent's benefit schedule passes through M, or in other words, $w(B) < M$ and $w(1) > M$. Thus the clumping at the minimum wage is composed of *informal* workers increasing wages by discarding benefits.[17]

[17] One can apply a modified version of this result to minimum wages in high enforcement countries. The benefits to the job might be defined not as legally required ones, but simply niceties of employment, such as those considered in Simon & Kaestner (2003). Regardless, if there are benefits workers can forego to make themselves worth the minimum wage, some may wish to do this instead of becoming unemployed. Since they value these other benefits as well as wages, once they hit the minimum wage they stop the trade-off. Thus the minimum wage may distort non-wage benefits decisions more than labor supply decisions, even with perfect enforcement. If non-wage benefits are more elastic than em-

Fixed Cost Nonconcavity Suppose there is a solution to (13) and call it $\hat{\tau}$. Since $w(\tau)$ has a fixed cost component, there is a nonconcavity which may make agents better off at the corner, $\tau = B$. An example of this situation is graphed in the second panel of Figure 3, where the agent is indifferent between their tangency level of benefits, $\hat{\tau}$, and full benefits. This nonconcavity is irrelevant if the worker has $w(B) < M$, for such a worker, $w < M$ or $\tau < B$; either way the worker must always pay the fixed costs of informality so there is no nonconcavity.[18] For workers who have the choice of formality, they choose $\hat{\tau}$ if $\psi(w(B), B) \leq \psi(w(\hat{\tau}), \hat{\tau})$, otherwise they stay at the formal corner with $\tau = B$.

3.3.3 Specifying ψ for an Analytical Solution

To provide a tractable solution to the agent's optimization problem, define the function ψ as:

$$\ln \psi(w, \tau) \quad = \quad (1+\theta) \cdot \ln \tau - \frac{1}{2}(\ln \tau)^2 \cdot + \ln w \tag{15}$$

where $\theta \in [0, \ln B]$. Over the available range of θ and τ, this log-quadratic form is concave and increasing, which meets the requirements of the model. Further, where differentiable, the marginal benefit ratio $-\frac{\psi_\tau}{\psi_w} = -\frac{\tau}{w} \cdot (1 + \theta - \ln \tau)$, which can be substituted into equation (13), along with equation (14), to yield:

$$\ln \hat{\tau} = \qquad \theta \qquad w < M$$

ployment, which seems reasonable, this may be an important place to look for distortions of the minimum wage in developed countries. Unfortunately, if informal workers are not plentifully available in survey data, there may be difficulty in identifying the parameters of interest.

[18]It may be the case that workers value benefits enough to want *more* than full legal benefits. Since many of the benefits are deferred cash or some type of payment in kind at best, this would be a strange situation. Although the model could deal with these people, I restrict the function ψ so that this does not happen. An extension to the model would consider non-legally required benefits, in which case such overvaluation might be very reasonable. But as the purpose of the paper is to model informality decisions, non-mandated benefits are ignored.

$$= \theta - \delta_M \quad w > M\,,\, \tau < B \tag{16}$$

Constraining θ to the space of $[0, \ln B]$ provides it a natural interpretation as the log of the level of benefits the agent *would* choose in a market with no evasion costs. Note that once benefits are full, there is no evasion cost anymore, so the agent plateaus at full benefits. This equation only describes the tangency condition, $\hat{\tau}$. As discussed above, the optimal decision may not be at a tangency. Given the specific functional form, one can return to the kink and nonconcavity issues presented generally and calculate the analytical solution.

Kink in $w(\tau)$ For many workers with $w(B) < M$, there is a level of benefits that can result in the worker's wage rising above M., such that the kinked wage schedule may affect them. Such agents can be divided into three groups based on their benefit preferences. Using equation (9), one can derive $\frac{\ln(\pi_F t)+\delta_i-\ln M}{1+\delta_M} + \ln(B)$ as the level of θ at which the agent has a tangency at the minimum wage, when coming from wages less than the minimum. This value is a function of productivity and the individual evasion cost δ. For notational convenience, let:

$$\bar{\theta}_{WM}(t,\delta) \equiv \frac{\ln(\pi_F t) + \delta_i - \ln M}{1 + \delta_M} + \ln(B), \tag{17}$$

where the subscript keeps track of the fact that this is a measure of distance between the minimum wage and $w(B)$ for the worker. Agents with θ above $\bar{\theta}_{WM}(t,\delta)$ choose wages below M. Appealing to the conditions in equation (16), those with $\theta < \bar{\theta}_{WM}(t,\delta) + \delta_M$ choose wages above the minimum at a tangency point. All those between these two levels, with $\theta \in [\bar{\theta}_{WM}(t,\delta) + \delta_M, \bar{\theta}_{WM}(t,\delta)]$, remain at the minimum wage.

Fixed Cost Nonconcavity Given a form for utility, one can derive the value of θ above which agents who can be formal choose to do so to avoid δ, $\tilde{B} + \delta_M - \sqrt{-2\cdot\delta}$. Note that if $\delta = 0$, this collapses down to the tangency condition in equation (16) for those above the minimum wage. Any worker with θ above this value and $w(B) > M$ chooses full benefits.

3.3.4 Regions

One can characterize each worker as falling into one of five regions in t, θ, δ, and ζ space. Let Ω_j be the jth region where $j \in \{1,2,3,4,5\}$. The five worker regions are defined as:

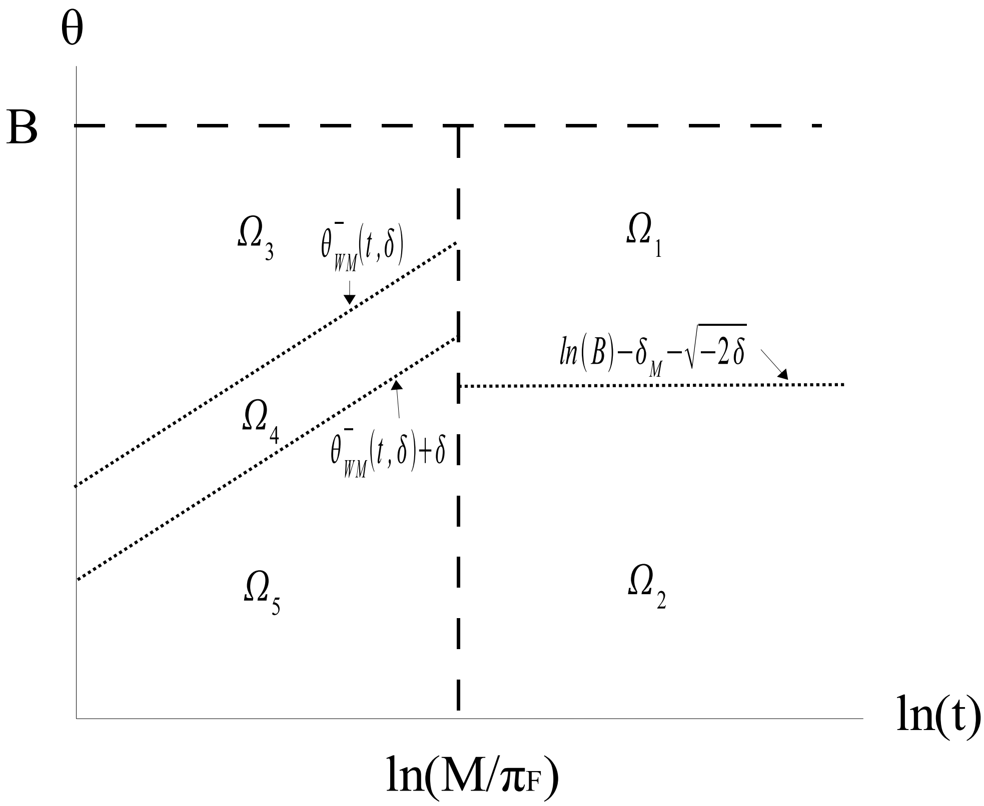
$$\begin{array}{l}
\Omega_1 = \{t,\theta,\delta,\zeta | t \geq \frac{M}{\pi_F}, \zeta \geq \ln\frac{(1+n)}{(1+n+\psi(w^*,\tau^*))}, \theta \geq \ln B + \delta_M - \sqrt{-2\cdot\delta}\} \\
\Omega_2 = \{t,\theta,\delta,\zeta | t \geq \frac{M}{\pi_F}, \zeta \geq \ln\frac{(1+n)}{(1+n+\psi(w^*,\tau^*))}, \theta < \ln B + \delta_M - \sqrt{-2\cdot\delta}\} \\
\Omega_3 = \{t,\theta,\delta,\zeta | t < \frac{M}{\pi_F}, \zeta \geq \ln\frac{(1+n)}{(1+n+\psi(w^*,\tau^*))}, \theta \geq \bar{\theta}_{WM}(t,\delta)\} \\
\Omega_4 = \{t,\theta,\delta,\zeta | t < \frac{M}{\pi_F}, \zeta \geq \ln\frac{(1+n)}{(1+n+\psi(w^*,\tau^*))}, \theta \in [\bar{\theta}_{WM}(t,\delta)+\delta_M, \bar{\theta}_{WM}(t,\delta)]\} \\
\Omega_5 = \{t,\theta,\delta,\zeta | t < \frac{M}{\pi_F}, \zeta \geq \ln\frac{(1+n)}{(1+n+\psi(w^*,\tau^*))}, \theta < \bar{\theta}_{WM}(t,\delta)+\delta_M\}
\end{array} \tag{18}$$

and are summarized in Figure 4. Note that the condition $w(B) \geq M$ is equivalent to $t \geq \frac{M}{\pi_F}$ and $\bar{\theta}_{WM}$ is defined above in equation (17).[19]

The figure outlines the five regions described in equation (18). The first region, Ω_1, is the only set of formal workers. Ω_2 are those workers able to be formal, but preferring informality due to their low valuation of benefits. Thus they are informal due to violating the benefits law. Those in Ω_3 value benefits but are insufficiently productive to be formal. Given that they have paid the fixed costs of evasion these workers pick the exact level of benefits they find attractive, as they pay no additional evasion costs for moving to their optimal point. Ω_4 consists of workers who trade off benefits so much that their wage climbs to the minimum wage, at which point they face the kink in the budget constraint. This makes further trade-offs undesirable and so agents in Ω_4 are clumped at the minimum wage. The last region, Ω_5, are workers who trade off enough benefits that their observed wage is above the

[19] $w(B) \equiv \pi_i t \geq M \Rightarrow \pi_i(B) = \pi_F \Rightarrow t > \frac{M}{\pi_F}$. $w(B) \equiv \pi_i t < M \Rightarrow \pi_i(B) < \pi_F \Rightarrow t < \frac{M}{\pi_F}$

Figure 4: Optimal Benefits in θ and t Space



minimum wage. Thus they are informal due to lack of benefits and appear to be like agents in region Ω_2. They differ in that they actually cannot be formal because adopting full benefits would lower their wage to below M.

3.3.5 Observable States

Given these regions, it is easy to map unobserved individual parameters into observed wages and states A through E. Table 3 summarizes how the model translates the observed choices back to unobserved preferences, productivity, and idiosyncratic evasion costs.

Table 3: Mapping Parameters to Observed States

State	Region	$\ln \tau^*$	$\ln w^*$
A	$\{t, \theta, \delta, \zeta\} \in \Omega_1$	$\ln B$	$\ln \pi_F + \ln t$
B	$\{t, \theta, \delta, \zeta\} \in \Omega_2 \cup \Omega_5$ $\{t, \theta, \delta, \zeta\} \in \Omega_4$	$\theta - \delta_M$ $\bar{\theta}_{WM}$	$\ln(\pi_F t) + \delta + (1 + \delta_M) \cdot \ln \frac{B}{\tau^*}$ $\ln M$
C	$\{t, \theta, \delta, \zeta\} \in \{\Omega_3 \cap \theta = \ln B\}$	$\ln B$	$\frac{\ln(\pi_F t) + \delta + \delta_M \ln M}{(1+\delta_M)}$
D	$\{t, \theta, \delta, \zeta\} \in \{\Omega_3 \cap \theta < \ln B\}$	θ	$\frac{\ln(\pi_F t) + \delta + \delta_M \ln M}{(1+\delta_M)} + \ln \frac{B}{\tau^*}$
E	$\{t, \theta, \delta, \zeta \mid \zeta < \ln \frac{(1+n)}{(1+n+\psi(w^*, \tau^*))}\}$	-	-

These states exhaust the available groups into which an agent falls. Note that all those in states A-D must satisfy the work condition of $\zeta \geq \ln \frac{(1+n)}{(1+n+\psi(w^*,\tau^*))}$. Also, state B includes all those in regions Ω_2, Ω_4 and Ω_5. State C only occurs if there is a mass point of agents with $\theta = \ln B$; the specified model allows for this clumping at the top end of θ's range.

3.4 Comparative Static Response to Minimum Wage Changes

The model allows for an efficiency units model of the minimum wage to generate a spike in workers at the minimum wage. This can be seen from the bottom panel of Figure 3 that shows how the change in relative prices creates a kink in the wage/benefits trade-off right at the minimum wage. This kink causes worker clumping.

The model also allows for workers to choose full benefits in order to avoid the costs of illegality, and for illegality to occur in two dimensions, benefits and minimum wage payments. Given this flexibility, one can estimate how changes in one regulation have the potential to affect the compliance with other regulations. One can also model the effect of minimum wage changes on employment, wages, wage inequality, and compensation. This section considers how changes in the the minimum wage affect informality, payroll evasion, observed wages in the formal and informal sectors, wage inequality, and employment. It first gives the steady state values for these outcomes and then shows how a change in the minimum wage changes them. This is done first assuming there are no employment effects, and then again with employment allowed to change.

Let $g(t,\theta,\delta)$ be the joint density of t, θ, and δ. To defer considering employment effects, assume that $\zeta \geq \ln\frac{(1+n)}{(1+n+\psi(w^*,\tau^*))}$ for all agents, so that there is full employment. Recall that Ω_j is the jth region in Figure 4 where $j \in \{1,2,3,4,5\}$. Note that region borders are a function of M. One can then write the fraction of the population that is formal as

$$\int\int\int_{\Omega_1} g(t,\theta,\delta)dtd\theta d\delta$$

and those taking full benefits as

$$\int\int\int_{\Omega_1} g(t,\theta,\delta)dtd\theta d\delta + \int_{-\infty}^{0}\int_{0}^{\frac{M}{\pi_F}} g(t,\ln B,\delta)dtd\delta$$

where the second integral is over the upper edge of Ω_3. The average wage is

$$\bar{w} = \begin{array}{c} \pi_F(\int\int\int_{\Omega_1} tg \cdot dtd\theta d\delta + \int\int\int_{\Omega_2\cup\Omega_5} \frac{tB}{\Delta\cdot\exp(\theta-\delta_M)} g \cdot dtd\theta d\delta \\ + \int\int\int_{\Omega_3} \frac{tB}{\Delta\cdot\exp(\theta)} g \cdot dtd\theta d\delta + \int\int\int_{\Omega_4} \frac{M}{\pi_F} g \cdot d\theta dtd\delta) \end{array}$$

And the average wages in the formal and informal sectors can be had by taking the average over the appropriate regions, so that average formal wages are:

$$\bar{w}_F = \frac{\pi_F \int\int\int_{\Omega_1} tg \cdot dtd\theta d\delta}{P(\{t,\theta,\delta\} \in \Omega_1)}$$

and average informal wages are:

$$\bar{w}_I \quad \frac{\pi_F\left(\int\int\int_{\Omega_2\cup\Omega_5} \frac{tB}{\Delta\cdot\exp(\theta-\delta_M)} g\cdot dtd\theta d\delta + \int\int\int_{\Omega_3} \frac{tB}{\Delta\cdot\exp(\theta)} g\cdot dtd\theta d\delta + \int\int\int_{\Omega_4} \frac{M}{\pi_F} g\cdot d\theta dtd\delta\right)}{P(\{t,\theta,\delta\}\in\Omega_2\cup\Omega_3\cup\Omega_4\cup\Omega_5)}$$

Figure 4 captures all the regions an agent can be in. A decrease in the minimum wage shifts the line $\frac{M}{\pi_F}$ leftward and causes the borders of region 4 to shift leftward as well, so as to maintain the same relative position. Thus as the regions shift, agents along the region borders are reassigned as follows: agents along the right border of regions three, four, and five become members of regions one and two; agents on the bottom border of region three and four become members of regions four and five. Further, there is another dimension in that the minimum wage causes some agents to become employed or stop working.

Lowering the minimum wage clearly increases the number of agents that are formal. Only agents in region 1 are formal, and as the minimum wage falls, Ω_1 gets bigger. This occurs for both mechanical and behavioral reasons; mechanically, the definition of formality is expanded by a lower minimum wage. Behaviorally, there are workers that become part of Ω_1 by adopting full benefits they previously didn't accept. For these workers, the lower minimum wage has caused a complementary shift in non-wage benefits.

A lower minimum wage also decreases payroll evasion, for exactly the reasons cited above. Payroll compliance is formal workers plus those that fully value benefits. Since the second group's preferences are unaffected by the minimum wage change, the only response is that more agents are now in Ω_1. Thus payroll evasion declines.

It requires more work to determine the effect of the minimum wage on average wages. Decompose the minimum wage change into three exhaustive channels:

$$\frac{d\bar{w}}{dM} = \frac{\partial \bar{w}}{\partial \frac{M}{\pi_F}} \cdot \frac{\partial \frac{M}{\pi_F}}{\partial M} + \frac{\partial \bar{w}}{\partial \bar{\theta}_{WM}} \cdot \frac{\partial \bar{\theta}_{WM}}{\partial M} + \frac{\partial \bar{w}}{\partial \Delta^{-1}} \cdot \frac{\partial \Delta^{-1}}{\partial M} \tag{19}$$

where the first term is restricted to changes in the average wage resulting from a shift in the region border $t = \frac{M}{\pi_F}$ separating regions 1 and 2 from regions 3, 4, and 5. Independently, the minimum wage affects $\bar{\theta}_{WM}$, which determines the clump that is observed at the minimum wage and it causes a change in the evasion cost each agent pays, because those with $w < M$ are now closer to the minimum wage.

Signing the first term, $\frac{\partial \bar{w}}{\partial \frac{M}{\pi_F}}$, requires determining what happens as agents that were on one side of $t = \frac{M}{\pi_F}$ move to the other side. Suppose that one is looking at a drop in the minimum wage, then this is the compilation of agents moving from regions 3, 4, and 5 to regions 1 and 2. Take each of these in turn.

$\Omega_3 \rightarrow \Omega_1$ Ω_3 is defined as those that choose high enough benefits that they have a wage below M. Thus $w < M$ because the evasion cost is larger than the payments from accepting low benefits. In Ω_1, these agents have no evasion costs, but take full benefits, resulting in $w = M$ since by definition the marginal agents are on the border with $t = \frac{M}{\pi_F}$. Thus wages rise in this case.

$\Omega_3 \rightarrow \Omega_2$ In this case, the agent increases benefits but not all the way to full. But if the agent chooses to do this it is only to get a higher wage, so that $w > M$. So once again, wages have increased.

$\Omega_4 \rightarrow \Omega_1$ Ω_4 consists of agents exactly at the minimum. But agents in Ω_1 with $t = \frac{M}{\pi_F}$ are also exactly at the minimum. Thus there is no first order change in wages.

$\Omega_4 \to \Omega_2$ As before, Ω_2 only has agents with $w > M$, so these agents also increase their wage.

$\Omega_5 \to \Omega_1$ This is the one odd case. Agents in Ω_5 ditch benefits enough to have an observed wage above the minimum. Thus moving to Ω_1 entails a higher total compensation because of the decreased evasion costs, but lower wages, since $w = M$ along the left border of Ω_1.

$\Omega_5 \to \Omega_2$ Moving the border between these two regions does not cause any change in wages.

So in three cases, a lower minimum wage causes a higher wage, in two cases the wage does not change, and in one case, the wage falls. Thus the sign of the first term is ambiguous, though it is negative in cases where Ω_5 and Ω_1 do not share a common border.

Return to Equation (19); the second of the three terms has no effect on wages. Agents that are on the borders between regions Ω_3, Ω_4, and Ω_5 have identical wages, no matter which region they are in.

The last term is composed of two parts, the first of which is positive because decreasing evasion costs increases wages for all agents with $t < \frac{M}{\pi_F}$. The second part is:

$$\frac{\partial \Delta^{-1}}{\partial M} = \frac{\delta_M}{\Delta \cdot M} \leq 0$$

Multiplying the two together, the third term is negative.

Compiling the three channels, a minimum wage decrease may have either a positive or negative effect on average wages, though it is negative unless an important role is played by agents that increase benefits so much that their wage falls.

Formal sector wages, which belong to those in Ω_1, fall as the minimum wage falls, since the new entrants are all along the lowest paid edge of the region. This is a straightforward composition effect. If one were only to look at those away from the border $\frac{M}{\pi_F}$, wages would remain the same.

The effect on informal sector wages is ambiguous. For those with $t < \frac{M}{\pi_F}$, decreasing evasion costs raise wages as the minimum wage falls. But this ignores composition effects, as many agents with relatively high productivity leave informality. If one only looks at informal agents with wages noticeably below the minimum wage, and averages over these workers, the composition effect disappears. For this group of low-skilled workers wages rise as the minimum wage falls.

Putting together the wage movements across sectors, although the effect on wages is in general ambiguous, wages between the very-skilled formal and very unskilled should move closer as the minimum wage drops. Thus the minimum wage increases inequality.

All of the analysis above ignores employment effects. A lower minimum wage unambiguously raises potential compensation, ψ, for all agents with $t < \frac{M}{\pi_F}$. Since agents work if $\zeta \geq \ln \frac{(1+n)}{(1+n+\psi(\cdot))}$, this higher compensation causes some agents to become workers. The higher compensation only occurs for the low-skilled. Thus low-skilled employment increases when the minimum wage falls. Entering workers all have productivity below $\frac{M}{\pi_F}$, but those in Ω_5 will be working at wages above the minimum; this ambiguity means one cannot predict how average *wages* change among workers *observed working*.

The compensation increase does not affect formal workers, so there is no formal employment increase.[20] Thus the employment effect of a lower minimum wage is to raise the number of employed informal workers relative to formal workers. *Among workers*, one cannot say whether formality should rise or decline, unless employment is known to remain the same, in which case, formality should move opposite from the minimum wage.

The entry of workers also complicates the informal wage comparative statics. Since the new entrants may be low-skilled, informal wages may rise or fall in the presence of employment changes.

Thus the model offers few unambiguous responses to changes in the mini-

[20] In general equilibrium, employment drives down the price π_F, causing formal workers to leave the market. This further reduces the observed fraction of the work force that is formal.

mum wage. Employment should rise, but effects on wages and formality are ambiguous. If employment is relatively constant, informal wages and wage inequality should move opposite of the minimum wage though high-skilled formal wages should be unaffected. Static employment predicts formality and payroll compliance should also move opposite the minimum wage. Average wages are always ambiguously signed.

4 Data

The data are annual, cross–sectional, individual observations on wages, labor market participation, benefits, and family characteristics drawn from one of Brazil's household surveys, the *Pesquisa Nacional de Amostra de Domicilios* (*PNAD*).[21] The survey interviews approximately 300,000 individuals every year. The estimation uses surveys from from 1981 to 1999 except 1991, when there was a national census, and 1994 when there were budgeting difficulties. Altogether, the dataset contains approximately five million observations. From this data, the estimation uses a random sample of 100,000 men.

Data are collected in October about experiences in September and include detailed labor force participation information, such as whether or not the individual participates in the social security system, possesses a legal work contract (which implies being registered with government), and their hours worked and earnings for the month. The hourly wage is constructed from the hours and earnings data which is then deflated using the *IPCA*. Agents with a work contract or who pay social security are classified as taking full benefits. Both employees and self-employed workers are included.

[21] The *PNAD* micro data is available from the Brazilian census agency, the *IBGE*. More information is available at their web site. The *PNAD* is not the only household survey data available in Brazil. There is also the *PME*, a monthly CPS-style survey that rotates households in and out of the sample over one year. Unfortunately the *PME* is drawn exclusively from the largest metropolitan areas, and hence is not nationally representative. The rural workers missed by the PME are especially relevant to formal and informal work. These rural workers make decisions about whether to migrate to a neighboring city to look for a job in the formal labor market. They also migrate back to the rural areas when formal sector jobs are scarce. The *PNAD* includes these workers and so is preferable.

The minimum wage is also deflated by the price index. Minimum wages are reported as a monthly salary which must be combined with the maximum hours one can work in order to get a minimum wage. Those working half-time are required to receive half the minimum wage. Thus it is truly a minimum wage, not just a minimum salary. The maximum hours worked changes over the sample period from 48 to 44 in 1988. For purposes of estimating the spike at the minimum wage, minimum wage workers are those working at the minimum monthly salary if they report working 40, 44, or 48 hours, or if their wage is within 3 log points of one of the wages implied by these hours. The minimum wage, the IPCA price index and GDP per capita, which are used in some regressions, all come from the Brazilian Central Bank's online database.

Full benefits are calculated based on the legal payroll taxes in Brazil (see section 2.1.1). The cost multiplier to the firm of these benefits is .7 log points, thus $\ln B = .7$.[22] Wages are computed by dividing earnings for the month of September by average hours worked.

Age is counted in decades and centered around 0. Thus it ranges from -2 to 2 and a value of 0 corresponds to a man age 35. Years of schooling is clumped in the data for higher levels. Those with 9-11 years of schooling are assigned a schooling level of 10. Those with more than 11 are assigned a value of 14. Years are measured in decades, with the first year, 1981, normalized to 0. Nonlabor income is all household income that does not come from the individual's wages. It includes the wage income of other agents in the household.

[22]Due to the 1988 constitution, payroll benefits actually differ before and after 1988. Thus up to 1988 $\ln B = \ln(1.84)$, and afterwards $\ln B = \ln(2.02)$. This regime shift may have other effects on the administration of benefits. To account for this, benefit preferences include an indicator variable that equals one for all years after the 1988 Constitutional change.

5 Specification

Given the above model, estimation requires specifying the observed variables and unobserved distributions to allow the model to assign a probability to any observed outcome. One can then use maximum likelihood for the estimation. Section 5.1 specifies the covariates and distributional assumptions, Section 5.2 discusses the likelihood function and Section 5.3 discusses identification.

5.1 Distributions and Covariates

Productivity and preferences for work are allowed to be correlated across workers, and are modeled as bivariate normally distributed variables:

$$\begin{aligned} \ln t_i &= X_i\beta + \varepsilon_i \\ \zeta_i &= Z_i\zeta_Z + u_i \\ (\varepsilon_i,\ u_i) &\sim \mathrm{BVN}(0, 0, \sigma_\varepsilon^2, \sigma_u^2, \rho) \end{aligned} \tag{20}$$

where X_i and Z_i are productivity and preference shifters.

The benefits parameter θ_i is distributed as a normal variable truncated to be between 0 and $\ln B$, generating mass points at 0 and $\ln B$. This allows many agents to value benefits fully or not at all:

$$\begin{aligned} \theta_i = &\quad U_i\theta_U + \eta_i \quad && U_i\theta_U + \eta_i \in [0, \ln B] \\ = &\quad 0 && U_i\theta_U + \eta_i < 0 \\ = &\quad \ln B && U_i\theta_U + \eta_i > \ln B \\ \eta_i \sim &\quad \mathrm{N}(0, \sigma_\eta^2) \end{aligned} \tag{21}$$

Where U_i is a set of benefit preference shifters.

Evasion costs also vary across individuals and are distributed as

$$-\delta_i \sim \text{Exp}(\sigma_\delta) \tag{22}$$

which ensures that cost is always negative.

Let π_F^k be the formal sector price in market k, where each agent is considered to be in one of K markets. Then one can recover formal sector prices, $\pi_F^1, \ldots, \pi_F^K$ with dummy variables that divide the data into markets.

If the whole economy in a single year functions as one labor market, so that $k = t$, then a single set of year dummies recovers all prices. The estimation does not impose this strong assumption on the data, but rather breaks up the country into markets by region and broad education group. The education categories are based on certificates received at the 4th and 8th grades, with a separate category for illiterate workers. With 17 years, four education groups, and two regions, the model has 136 markets.

Note that productivity can differ across each year of education, the restriction imposed here is that workers within a region/education/year cell are all operating within one market, and so there is one applicable π_F^k value. This approach requires more data, but imposes fewer restrictions on how workers of different educational levels are related in their productivity, or in how that relationship changes over time.

The covariates in the productivity equation X_i include interactions and polynomials in age, education, and region. The work and benefit preference covariates, Z_i and U_i, include X_i plus family demographics, and a year trend. Due to the large changes surrounding the 1988 Constitution, a dummy variable is included for post-1988.

Note that only wages are affected by prices and only work decisions are influenced by nonlabor income, creating additional exclusion restrictions that aid identification. Nonlabor income is measured as the household income excluding the agent's own labor income.

5.2 Likelihood Function

Estimation requires finding values for the vector

$$[\{\pi_F^1 \dots \pi_F^K\}, \beta, \zeta_Z, \theta_U, \sigma_\varepsilon, \sigma_u, \rho, \sigma_\eta, \delta_M, \sigma_\delta].$$

The theoretical model coupled with distributional assumptions about the parameters provides sufficient information to generate a likelihood of observing any wage-benefit-work combination.

Each worker has the following heterogeneous draws, none of which are directly observed: a productivity level, t; a preference for work, ζ; a preference for benefits, θ; and an individual evasion cost, δ.[23] For each worker, one must determine the probability that they have a draw that places them in their observed state (A-E) with their observed wage. Let Table 3 define $\tau^*(t, \theta, \delta)$ and $w^*(t, \theta, \delta)$. Since benefits are only observed as full or less than full, define $b^*(t, \theta, \delta) = 1$ if benefits are full ($\tau^*(t, \theta, \delta) = B$) and 0 otherwise. With these functions in hand, it is easy to specify the work decision:

$$W = \mathbf{1}\left(\zeta \geq \ln \frac{(1+n)}{(1+n+\psi(w^*, \tau^*))}\right)$$

based on the criteria laid out in Section 3.3.2, with $\mathbf{1}(\cdot) = 1$ if the inequality is true and 0 otherwise. The arguments of w^* and τ^* are suppressed, but they are deterministic functions of t, θ, and δ. With this notation, states A-D correspond to the four combinations of: wages above and below the minimum and b equal to 0 or 1, all with $W = 1$. State E, for nonworkers, includes all those with $W = 0$.

Let $f(\zeta, t, \theta, \delta)$ be the joint density of the four random terms ζ, t, θ, and δ . Let $f_{x|y}(x)$ be the joint density of x conditional on y. The likelihood function for any given agent requires integrating over all the probabilities that give the observed outcome state and, for workers, their wage. This is done by breaking up the joint density into a set of conditional densities and

[23] Individual subscripts are suppressed throughout this section, as are the market subscripts for π_F.

then evaluating each conditional density in order. This involves finding a restriction in the ζ space that satisfies the work condition given t, θ, and δ. For workers, one next determines the productivity level t that yields the observed wage and benefit levels given θ and δ. θ and δ are in turn restricted to the space that could give the observed wage and benefit combination. Consider each state in turn:

A — Formal Workers— $w \geq M$, $b = 1$

These are the workers in Ω_1. The likelihood of observing such an agent is:

$$\int_{-\infty}^{0} \int_{L^A}^{\ln B} \int_{L_\zeta}^{\infty} f_{\zeta|t,\theta,\delta}(\zeta) d\zeta f_{\ln t|\theta,\delta} \left(\ln \frac{w}{\pi_F} \right) f_{\theta|\delta}(\theta) d\theta f_\delta(\delta) d\delta$$

where

$$L_\zeta = \ln \frac{(1+n)}{(1+n+\psi(w^*, \tau^*))},$$

and

$$L_\theta^A = \ln B + \delta_M - \sqrt{-2\delta}.$$

The likelihood function allows for any value of δ, but restricts θ to the Ω_1 region. Since benefits are full and no evasion costs are paid, it is straightforward to determine the productivity level as a function of the wage. Lastly, the ζ space is integrated over the space where agents choose to work.

B — Workers Informal By Benefits— $w \geq M$, $b = 0$

These are workers from Ω_2 , Ω_4, and Ω_5. Since the workers in Ω_4 are clumped at the minimum wage they will need to be treated separately. But the other two regions are inseparable. For those not clumped at the minimum wage, the likelihood function is:

$$\int_{-\infty}^{0} \int_{0}^{L_{\theta,1}^B} \int_{L_\zeta}^{\infty} f_{\zeta|t,\theta,\delta}(\zeta) d\zeta f_{\ln t|\theta,\delta} \left(L_{t,1}^B \right) f_{\theta|\delta}(\theta) d\theta f_\delta(\delta) d\delta$$

where

$$L^B_{\theta,1} = \ln B + \delta_M + \max(-\sqrt{-2\delta}, \frac{\ln M + \delta - \ln w}{1 + \delta_M})$$

$$L^B_{t,1} = \ln(\frac{w}{\pi_F}) - (\delta + (1 + \delta_M) \cdot (\ln B - (\theta - \delta_M)))$$

and L_ζ is as defined above. These workers must value benefits less than those in state A. The limit $L^B_{\theta,1}$ combines the productive workers in region Ω_2 with the less productive in Ω_5. Crossing from one region to the next, the top edges of these two regions are not required to line up (see Figure 4), thus the max function allows for all the possible θ values. The productivity level, $L^B_{t,1}$ comes from inverting the wage function (9) using the observed wage. When computing productivity, θ is treated as a given so the optimal benefits level is known.

For those at the minimum wage the likelihood is:

$$\int_{-\infty}^{0} \int_{0}^{L^B_{\theta,2}} \int_{L^B_{t,2}+(1+\delta_M)\cdot\delta_M}^{L^B_{t,2}} \int_{L_\zeta}^{\infty} f_{\zeta|t,\theta,\delta}(\zeta) d\zeta f_{\ln t|\theta,\delta} (\ln t)\, d\ln t\, f_{\theta|\delta}(\theta) d\theta f_\delta(\delta) d\delta$$

where

$$L^B_{\theta,2} = \ln B + \delta_M + \frac{\delta}{1 + \delta_M}$$

$$L^B_{t,2} = ((1 + \delta_M) \cdot (\ln w^* - (\ln B - \theta)) - (\ln \pi_F + \delta + \delta_M \ln M).$$

This group is known to come from below the minimum wage, so that there is no more max function in the benefits limit. Because of the clumping, an exact productivity level can't be determined. Instead one integrates over the range of values that would generate the observed clump. The limits of integration come from combining the region information from Ω_4 with the wage function.

C — Workers Informal By Wages— $w < M$**,** $b = 1$

This is the subset of workers that are in Ω_3 and fully value benefits. This requires that $\theta = \ln B$ and the likelihood function to be:

$$\int_{L_\delta^C}^{0} \int_{L_\zeta}^{\infty} f_{\zeta|t,\theta=\ln B,\delta}(\zeta) d\zeta f_{\ln t|\theta=\ln B,\delta} \left(L_t^C\right) f_{\delta|\theta=\ln B}(\delta) d\delta \cdot P_\theta(\theta = \ln B) \cdot (1+\delta_M)$$

where

$$L_t^C = ((1+\delta_M) \cdot \ln w^*) - (\ln \pi_F + \delta + \delta_M \ln M),$$

$$L_\delta^C = (1+\delta_M) \cdot (\ln w - \ln M),$$

and $P_\theta(\theta = \ln B)$ is the unconditional probability that $\theta = \ln B$. The restriction on δ was not required in previous states. Note that an agent with a wage just below the minimum cannot have very high evasion costs and a high valuation of benefits, because if the agent did not pay the evasion cost δ, they would be above the minimum wage, and their high valuation of benefits assures that they would be willing to take full benefits. Thus they could be legal, get a higher wage, and more benefits. So their current position is not possible. In effect, for any given θ, there is a restriction on allowable δ's.[24]

D — Workers Informal By Wages and Benefits— $w < M$**,** $b = 0$

These workers are the rest of region Ω_3. The likelihood function is very similar to those in state C:

$$\int_0^{\ln B} \int_{L_\delta^D}^{0} \int_{L_\zeta}^{\infty} f_{\zeta|t,\theta,\delta}(\zeta) d\zeta f_{\ln t|\theta,\delta} \left(L_t^D\right) f_{\delta|\theta}(\delta) d\delta f_\theta(\theta) d\theta \cdot (1+\delta_M)$$

with

$$L_t^D = \left((1+\delta_M) \cdot (\ln w^* - \ln\left(\frac{B}{\tau^*}\right)\right) - (\ln \pi_F + \delta + \delta_M \ln M),$$

[24] It should be obvious that this could also be written as a restriction on θ given δ. The problem with that approach is that it interacts with the Ψ restriction to create more dead zones. This is because of the partial observability of θ. Since δ is never observed, there are always values it can take to satisfy the restriction.

$$L^D_\delta = (1 + \delta_M) \cdot (\ln w - \ln M + (\ln B - \theta)).$$

The limits L^D_t and L^D_δ are the same as those for state C, except that they now include a term for the change in benefits. On the integration over θ, the $\ln B$ upper limit is an open set, so that $\ln B$ is not included. Those workers at $\theta = \ln B$ were dealt with above as state C.

E — Nonworkers

This likelihood function is:

$$\int_{-\infty}^{0} \int_{0}^{\ln B} \int_{-\infty}^{\infty} \int_{-\infty}^{L_\zeta} f_{\zeta|t,\theta,\delta}(\zeta) d\zeta f_{\ln t|\theta,\delta}(\ln t) d \ln t \, f_{\theta|\delta}(\theta) d\theta f_\delta(\delta) d\delta.$$

None of the integrals in this section are analytically tractable. The Appendix discusses the numerical algorithm used to compute them.

5.3 Identification

Given the above model and a draw from the distributions of productivity, preferences and evasion costs, one can determine the probability that a worker adopts any observed work, wage, and benefits choice.

Prices and productivity covariate parameters are readily identified by the formal sector agents. The exclusion restrictions between the productivity and work equations identifies the variance, correlation, and covariate parameters on the work equation.

The benefits equation is more difficult to pin down. First note that one can easily identify $\frac{\theta_U}{\sigma_\eta}$ as in any standard probit model. But to identify the two parameters separately requires a shifter to the index cutoff value that has a known magnitude. This role is played by the δ_M parameter which causes agents above and below the minimum wage to have different cutoffs. δ_i serves the same purpose but is not observed and so isn't as useful for identification. Further identification comes from comparing wages of those who take full benefits and those who don't. If covariates affect wages differently between the two regimes, this identifies the effect of different preferences for benefits (although some of the effect will be through the evasion parameters). Wages that seem abnormally high for those without benefits, in a way that is orthogonal to all covariates, are attributed to the benefits error term, which further identifies the variance of the benefits equation.

Finally, the evasion parameters each have multiple sources of identification. δ_M affects the covariates of all informal employees, it affects differential benefit take-up rates between those above and below the minimum wage, and it is the cause of a spike in workers at the minimum wage. σ_δ is the variance of the individual component of evasion costs. It is identified by wage drops among informal workers that are orthogonal to covariates. Note that the benefits error term also affects wages for workers who choose less than full benefits. So if the benefits equation is not well-identified by other sources, σ_δ and σ_η will be difficult to differentiate. This problem is alleviated because σ_η does have alternate identification power, and from the fact that workers below the minimum wage who choose full benefits are subject to changes due to σ_δ, but are unaffected by changes in the value of σ_η. These workers provides a unique source of identification for σ_δ.

As this discussion should make clear, identifying the parameters does not require time-series variation. The work preference equation *does* require multiple markets as identifying variation in the price equation, and the estimation uses time-series as one source of this variation. But identification could be achieved with any set of multiple markets, such as regional markets or markets divided by education level. All other parameters can be recovered from the cross-section, without appealing to any time-series element whatsoever. [25]

[25] Measurement error in the price index would not directly affect the original estimation of evasion cost parameters, as these are based on log differences that are indifferent to the price index used. The participation decision would also be indifferent to the price index if it were based on a pure comparison between incomes. Unfortunately, some distortion may enter because consumption has a 1 added to it to avoid 0's in the utility log function. Since the 1 can't be multiplied by the price index error, there is the possibility of distortion in the participation decision. Obviously, inconsistency in one equation can indirectly cause

One route researchers take in dealing with short time series is to treat each state or region as a separate observation, creating a panel of state-years. While this can solve many problems, it has difficulty precisely identifying covariates that only vary at the national level, such as national (as opposed to local) labor laws, and is subject to concerns about measurement error in the price index.

Brazil's inflation, which can run into thousands of percentage points a year, clearly causes concerns about accurate data. If measurement error from price indices is classical, it will attenuate employment effects, but will create a correlated bias when wages are regressed on the minimum wage. Since both regressor and regressand are affected by the same error, least squares regression will infer a positive relationship even if none exists. Thus measurement error would bias a model that relies upon time series variation towards finding that the minimum wage raises wages but has no employment effect.

The approach here allows identification by modeling how the minimum wage or benefit level affects a utility maximizing agent. Since the minimum wage will affect different agents very differently, this creates variation in the "treatment" which can be used for identification, even if the level of the minimum wage is held constant. Like the other approaches discussed, it depends on untestable assumptions. But when time-series are short, and suffer from intertemporal measurement error, these assumptions may be a welcome alternative approach.

6 Results

The probabilities in Section 5.2 provide the basis for estimating the parameter vector using maximum likelihood. As the integrals defining the probabilities are analytically intractable, their values are calculated with numeric simulation as described in the Appendix. Section 6.1 estimates the model assuming that the parameter vector is constant across all men. Section 6.2

inconsistent estimates in the rest of the model, but there is no direct effect of measurement error on the evasion parameters.

allows for education and geographic heterogeneity in the evasion parameters. Lastly, Section 6.3 considers how well the estimated model fits the observed data.

6.1 Homogeneous Model

Table 4 reports estimates of the model for approximately 100,000 working age men. Reported standard errors are robust to dependence within a year/region/education cell, but are likely to be too small in general due to lingering correlations across years and education groups even after the included covariates

The table lists each equation along with the associated vector of covariates if any. The productivity distribution gives results that are to be expected: there are nonlinear productivity increases associated with age and education. Note that the education parameters are estimated off education differences *within* a broad education market.

The second equation in Table 4 is the positive value given to work. Conversely, it could be read as the negative of preferences for leisure. Both age and education show substantial nonlinearity and education's effect varies across the two regions. The values are very large in size. This is because one compares the utility of a week's work to the utility of staying at home for a week. As family size increases, agents prefer to work less; but children, who demand more cash resources, increase the comparative value of cash over leisure for men.

The standard deviation of productivity and work preferences need little comment, although note that work preferences are very diffuse across the population, thus the male population has a low elasticity of work force participation. This result may be biased by price index measurement error that attenuates estimates of how prices affect work effort. The ρ term is negative implying that more productive agents have a stronger dislike for work, or a higher relative preference for leisure.

Table 4: Model Estimates

Parameter	Covariate	Estimate	Std Err
Productivity—β			
	Age	0.2449	0.0094
	Age Squared	-0.1071	0.0040
	Age Cubed	0.0041	0.0029
	Educ	0.0477	0.0081
	Educ*Southeast	0.0406	0.0113
	Educsq	0.0073	0.0005
	Educsq*Southeast	-0.0033	0.0006
Work—ζ_Z			
	Age	-0.8193	0.1807
	Age Squared	-3.5444	0.2227
	Age Cubed	1.2158	0.0868
	Educ	-0.7161	0.1307
	Educ*Southeast	1.3751	0.1905
	Educsq	0.0423	0.0094
	Educsq*Southeast	-0.0893	0.0147
	Southeast	-1.5784	0.5062
	Family Size	-0.5292	0.0542
	Children	1.2741	0.0990
	Year	-2.2269	0.2071
	Constant	19.5452	1.2929
Benefits —θ_U			
	Post88	0.1538	0.0156
	Age	0.0242	0.0066
	Age Squared	-0.0582	0.0031
	Age Cubed	0.0165	0.0026
	Educ	0.0725	0.0055
	Educ*Southeast	0.0026	0.0066
	Educsq	-0.0009	0.0004
	Educsq*Southeast	-0.0013	0.0005
	Southeast	0.2509	0.0205
	Family Size	-0.0073	0.0015
	Children	-0.0118	0.0023
	Year	-0.2277	0.0133
	Constant	0.1081	0.0184
Productivity Std. Dev—σ_ε		0.7322	0.0044
Work Std. Dev—σ_u		14.0470	0.7046
Benefits Std. Dev.—σ_η		0.5224	0.0085
Productivity and Work Correlation—ρ		-0.2792	0.0251
Evasion Cost—δ_M		-0.3913	0.0082
Evasion Std. Dev.—σ_δ		0.0145	0.0011
Observations		99831	
Log Likelihood		-181050	

The benefits preference coefficients show reasonable values. The 1988 reform resulted in an increased valuation of benefits. The age profile shows an inverted U-shape and education leads to a stronger desire for the legal benefits.[26] Those in the South strongly prefer more benefits and the valuation of benefits has shown a strong secular decline over time. Recall that the year variable is recorded in decades, thus there is about a .44 drop over the two decades, mediated by the rise of .15 in 1989. Family size has a small but negative effect on the benefits distribution perhaps due to the safety net provided by the family. The coefficient on children is economically significant. More children implies a lower preference for benefits, which is in line with the theory that the state's old age safety net substitutes for children as a net.

Preferences for benefits are very diffuse, given the mean. Values for the parameter lie between 0 and approximately .7, so the standard error of .52 shows that there is a great deal of variation in the population. This implies that there will be many agents who could benefit from working informally and trading benefits for wages.

The evasion cost parameters show that the there is a nontrivial amount of distortion coming from minimum wage enforcement. The marginal "evasion tax" δ_M, which is a cost based on how far you are from legality, is -.39. This means that agents pay about 40% of any increased illegality in increased evasion costs. Thus a worker below the minimum wage who had their productivity decline by 1% would be paid $\frac{1\%}{1-.4} = 1.66\%$ less.

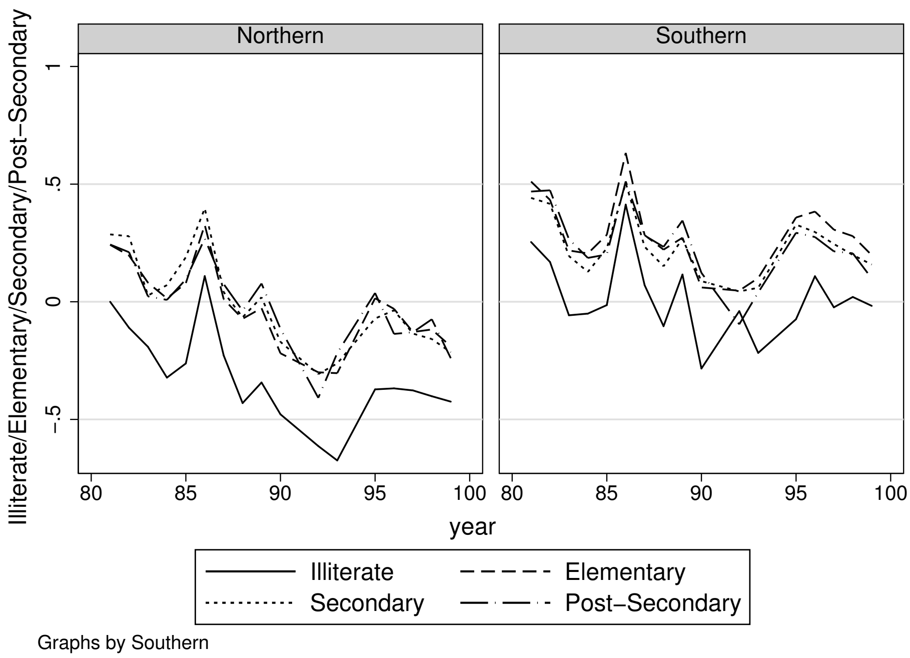
The agent's fixed cost of evasion is drawn from an exponential distribution with mean and standard deviation σ_δ. Thus an agent at the average of this distribution moving into the informal market could expect a 1.5% discrete drop in wages. This hides the heterogeneity in the effect as one would observe many people with essentially no fixed costs of evasion, while a few others face a cost of 5% or more. Regardless, the effect is small enough that apparently

[26] This parameter is unfortunately not as "deep" as one might wish. It could well be the case that the preference for benefits by the educated is because the educated actually receive the benefits whereas the poor pay for benefits they cannot really take full advantage of. The same issue comes up in evaluating the regional differences.

the larger cost comes through the marginal evasion parameter, δ_M.

As mentioned in section 5.1, prices are estimated separately using dummy variables by year and region for 4 broad educational categories. They are graphed in Figure 5. The normalizing value is the price of a unit of illiterate labor in 1981 in the North. Prices are higher in the South and are very similar across educational categories– suggesting that all *literate* workers within a region could probably be treated as one market if desired. Illiterate workers receive a lower price for their labor (controlling for a quadratic education effect in productivity) and don't move entirely the same as the other markets. Thus it is good to treat them separately, especially when the goal is to understand informality and low–wage work. Lastly, prices vary sharply from year to year and have generally fallen over the past twenty years. This is consistent with the descriptive work done in McIntyre & Pencavel (2001), which shows the same trends and variation in Brazil's wage distribution.

Figure 5: Formal Sector Prices



This model shows that agents generally do not fully value their benefits. They face large costs of evading the law, but despite this, many of them evade, either because they have no other labor market option or because they place very low value on non-wage benefits.

6.2 Heterogeneous Evasion Cost Parameters

Section 6.1 estimates the basic model, but fails to account for important heterogeneity. Namely, it may be the case that evasion costs differ sharply across the country and across education levels. It may be very easy to find an illegal job among unskilled laborers, but almost impossible among the jobs requiring more than a high school degree. This would imply that evasion costs are higher among the well educated. A similar difference might separate the richer South from the poorer, and less compliant, North. It may be that evasion is easier when others are evading as well, creating complementarities in evasion that cause the parameters to differ by region. Although this model can't fully explore legal enforcement complementarities, it can provide a different set of evasion costs to allow for different equilibria in the two regions.

Generalize the model in the following way:

$$\delta_{Mi} = \delta_M^0 + \delta_M^1 \cdot \text{South}_i + \delta_M^2 \cdot \text{Educ}_i + \delta_M^3 \cdot \text{South}_i \cdot \text{Educ}_i$$

$$\ln(\sigma_{\delta i}) = \sigma_\delta^0 + \sigma_\delta^1 \cdot \text{South}_i + \sigma_\delta^2 \cdot \text{Educ}_i + \sigma_\delta^3 \cdot \text{South}_i \cdot \text{Educ}_i$$

These generalizations allow evasion costs to change linearly by education, with each region treated independently. Table 5 provides estimates of this generalization.[27] The estimates of the non-evasion cost parameters are almost unchanged from what was reported in section 6.1. The only change

[27] Parameterizing evasion costs as a linear function of education by region can be problematic since neither parameter is defined over the entire real line. This does not turn out to be a problem for δ_M, so for simplicity a linear form is maintained. σ_δ is much closer to zero, so to avoid having the likelihood function encounter nonsense negative values for a variance, the log-linear specification is used.

of note is that the benefits equation, which gives the mean value for θ_i, has a a lower coefficient on the region dummy Southeast. It moves from .25 to .20, implying that estimated preference differences between regions were to a small degree just picking up the regional heterogeneity in evasion costs. Even this change is fairly minor.

The heterogeneous evasion cost estimates are easier to appreciate when graphed, which is done in Figures 6 and 7. δ_M varies from -.3 among the low-schooling population in the North to a much more severe -.6 among the well educated in the North, with the effect about as strong among educated Southerners. The South apparently is more uniform in its enforcement of law across education levels, since the costs do not change so sharply as they do in the North. These are substantial costs, especially among the highly educated.

This is reversed in the $\sigma_{\delta i}$ parameter, which is economically relevant only among the poorly educated. The estimated fixed cost has a mean and standard deviation that is never more than .04, making it a fairly inconsequential part of the overall cost.

These results suggest that enforcement does in fact rise with education and is more stringent in the South than the North. Of course, most well educated workers are sufficiently productive that the minimum wage law is not a binding constraint. So although they face higher costs of evasion, far fewer of them need to evade the law in order to work.

6.3 Model Fit

How well does the model predict behavior out of sample? To determine this, draw a sample of workers not used for the estimation and compare their outcome to the simulated outcome. This section compares the wage distributions, benefit levels across wage levels, and a variety of aggregate and individual measures of fit.

Table 5: Heterogeneous Evasion Cost Model Estimates

Parameter	Covariate	Estimate	Std Err
Productivity—β			
	Age	0.2455831	0.009393
	Age Squared	-0.1039201	0.00406
	Age Cubed	0.0026596	0.002866
	Educ	0.064143	0.00887
	Educ*Southeast	0.0227146	0.01174
	Educsq	0.0064972	0.000516
	Educsq*Southeast	-0.0025082	0.000652
Work—θ_Z			
	Age	-0.8120112	0.180393
	Age Squared	-3.531772	0.220349
	Age Cubed	1.211229	0.086226
	Educ	-0.7206441	0.130509
	Educ*Southeast	1.379114	0.189995
	Educsq	0.04269	0.009424
	Educsq*Southeast	-0.0895932	0.014638
	Southeast	-1.594071	0.505403
	Family Size	-0.5261981	0.053734
	Children	1.267254	0.098212
	Year	-2.214139	0.205993
	Constant	19.48229	1.279907
Benefits —ζ_U			
	Post88	0.1450293	0.015678
	Age	0.0245496	0.006691
	Age Squared	-0.0571552	0.003147
	Age Cubed	0.0159351	0.002695
	Educ	0.0736071	0.006625
	Educ*Southeast	-0.001128	0.007945
	Educsq	-0.0016403	0.000446
	Educsq*Southeast	-0.0006	0.000536
	Southeast	0.2036225	0.023324
	Family Size	-0.0075936	0.001558
	Children	-0.0116555	0.002217
	Year	-0.2238975	0.013253
	Constant	0.1218869	0.020751
Productivity Std. Dev—σ_ε		0.7316475	0.004457
Work Std. Dev—σ_u		14.00143	0.696284
Benefits Std. Dev.—σ_η		0.5244	0.0075
Productivity and Work Correlation—ρ		-0.2880863	0.025134
Evasion Cost—δ_M	Educ	-0.021578	0.001784
	Educ*Southeast	0.0106801	0.002416
	South	-0.1211346	0.013897
	Constant	-0.2926257	0.009615
Log Evasion Std. Dev.—$\ln(\sigma_\delta)$	Educ	-0.2305842	0.054822
	Educ*Southeast	0.0339829	0.063749
	South	-0.3768104	0.296099
	Constant	-3.333147	0.231183
Observations		99831	
Log Likelihood		-180843	

Figure 6: δ_M Evasion Costs by Education and Region

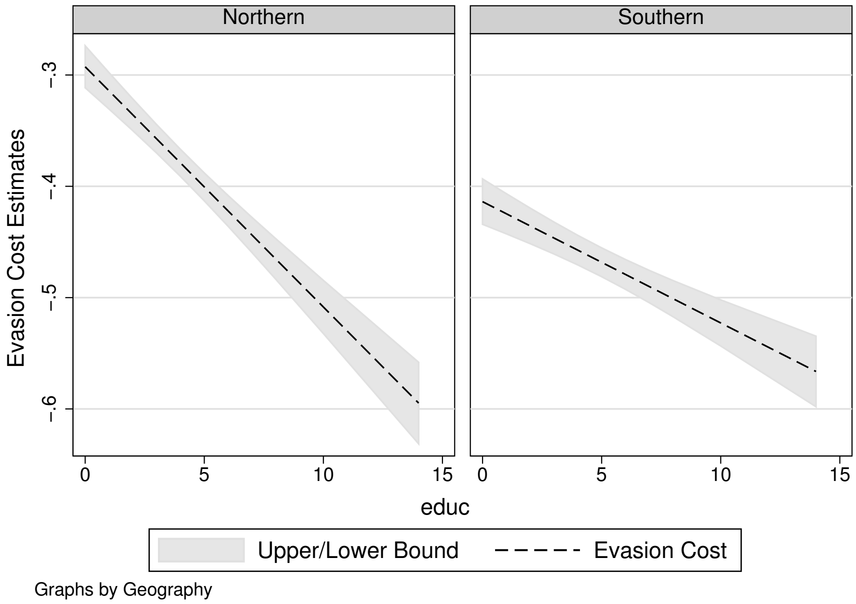
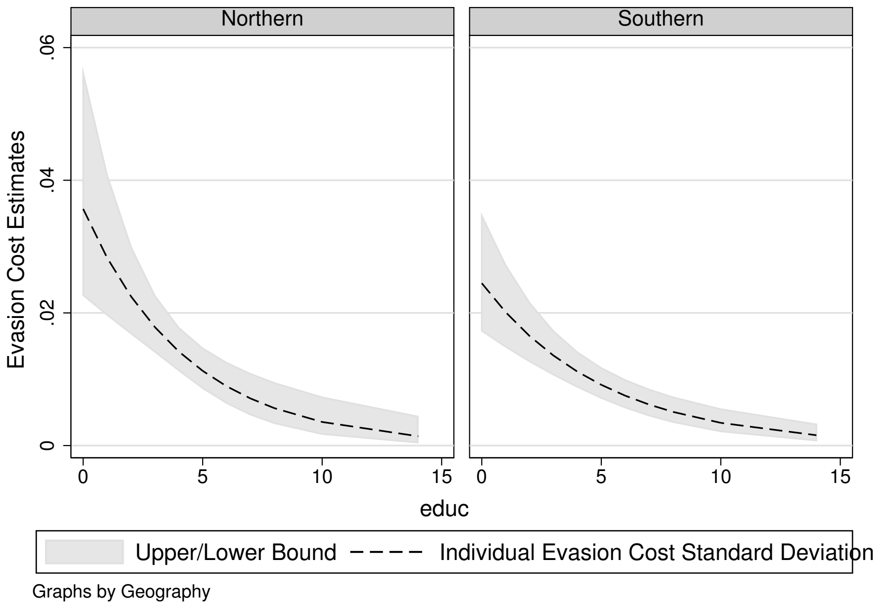


Figure 7: σ_δ Evasion Costs by Education and Region



6.3.1 Wage distribution

Figure 8 simulates the wage distribution for each of the 17 years in the data. Several of these years show noticeable spikes at the minimum wage and show a vacated left tail. The vacated left tail is *not* a result of unemployment, it is the result of agents raising their wage by opting out of benefits. For comparison, Figure 9 plots the empirical wage distributions from the same period. The distributions share similar characteristics, so that the model is capable of replicating the observed distribution, at least in its rough outline.

6.3.2 Benefits Across the Wage Distribution

Figure 10 compares wages to the percentage receiving full benefits, in the simulation (the dashed line) and empirically (the solid line). The simulation stays fairly close to the empirical reality, though it predicts too many full benefits holders in the far left tail of the wage distribution. It also shows a sharper jump in benefits at the minimum wage, while the empirical results are smoother.

6.3.3 Aggregate and Individual Prediction

Table 6 compares the simulation with the empirical results on several aggregate and individual predictors. Summary statistics include percentages working, formal, and getting full benefits, and several moments and quantiles of wages. The sampling error, which is tiny, is listed below each simulated result. [28]

In general, the simulated and empirical models are quite close. The participation decision is particularly tight, while the benefits decision is a few

[28] Bootstrapping is used to compute the sampling error in the simulation. This is done by repeatedly drawing a new vector of parameters from the sampling distribution and redoing the simulated policy change, then computing the sampling error in the simulation using the variance across all the simulated policy effects. The sample size is sufficiently large that the coefficient vector is almost certainly normally distributed, and so the simulation draws come from a normal distribution.

Figure 8: Simulated Wage Distribution

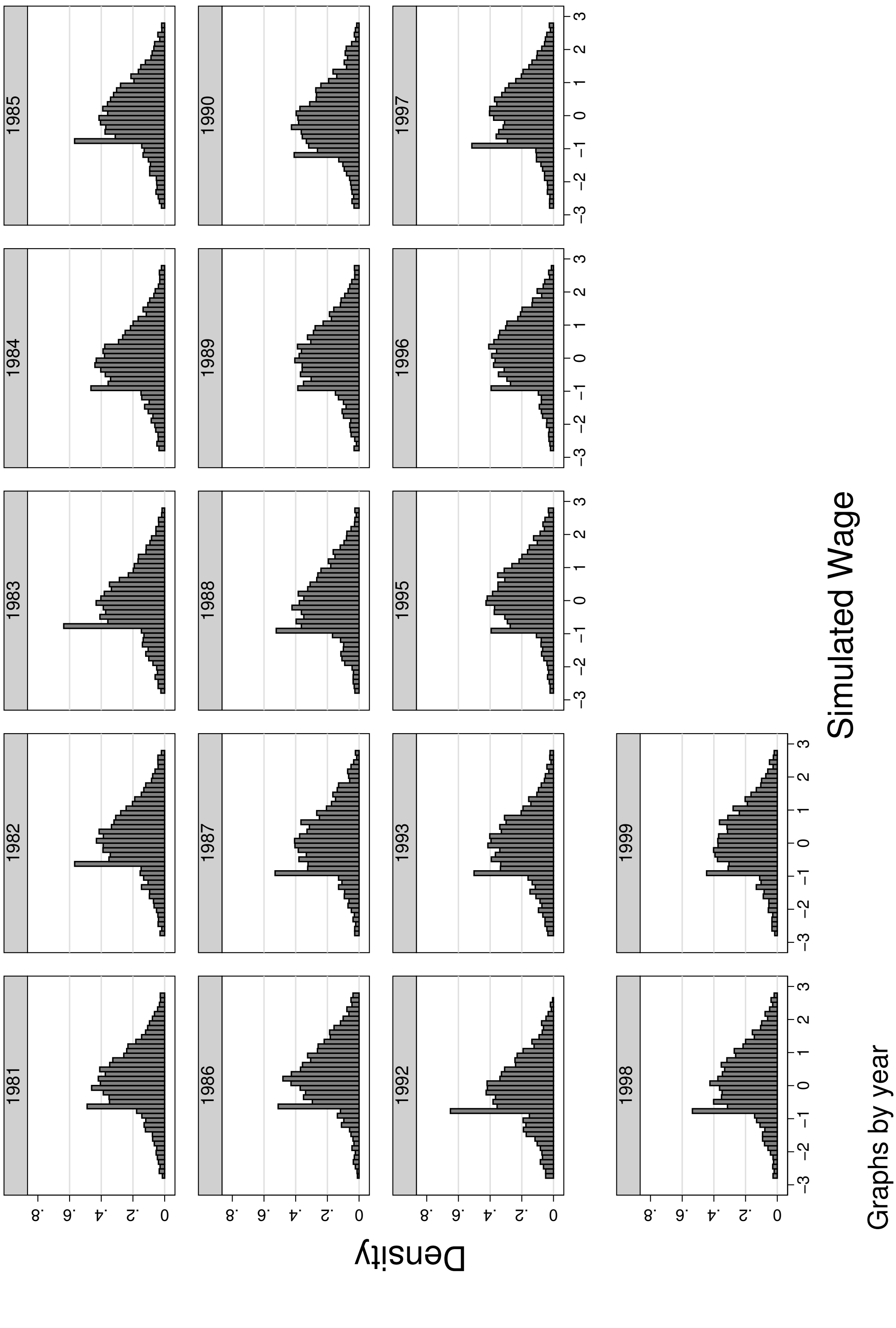


Figure 9: Empirical Wage Distribution

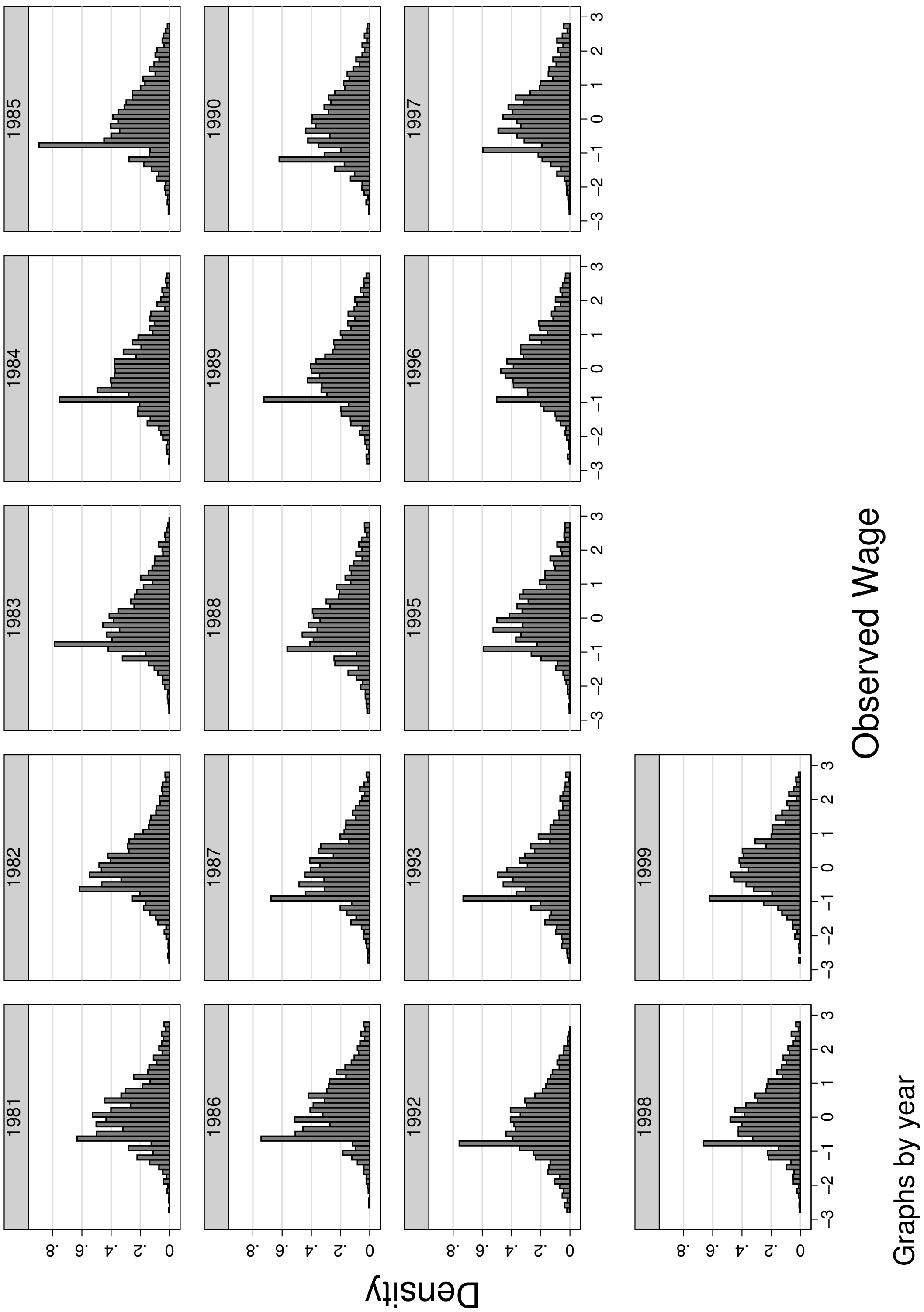
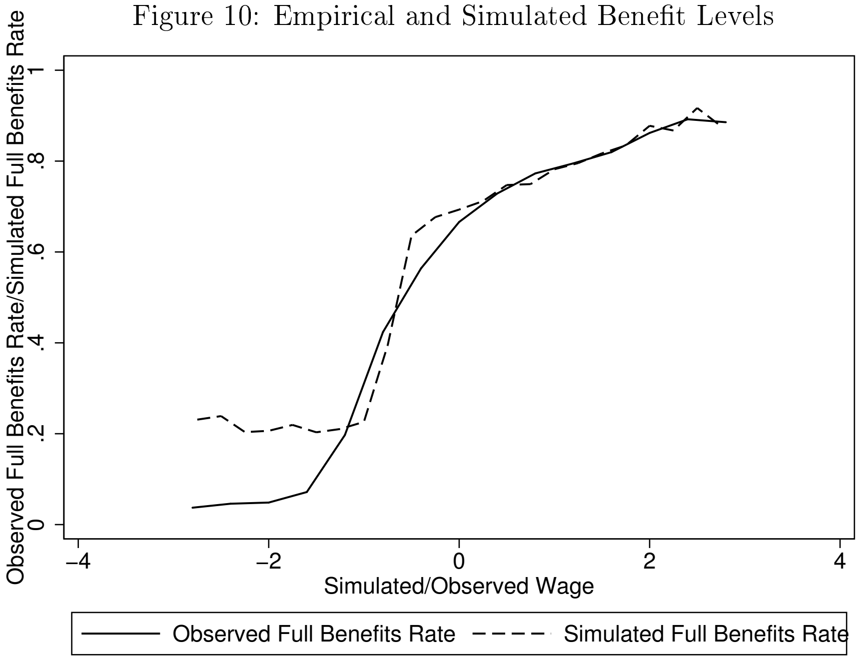


Table 6: Empirical vs. Simulated Outcomes

Statistic	Empirical	Simulated
% Employed	0.779	0.776
		0.002
% Formal	0.545	0.573
		0.005
% At Legal Benefits Level	0.579	0.610
		0.005
% Wage less than M	0.168	0.169
		0.004
% Wage $\geq M$, Partial Benefits	0.287	0.259
		0.006
% Wage $= M$	0.064	0.054
		0.002
% Wage $= M$, Partial Benefits	0.046	0.049
		0.001
% Wage $= M$, Full Benefits	0.019	0.006
		0.001
Average Wage	1.771	1.717
		0.023
Wage Std. Dev.	2.915	2.502
		0.093
Wage Skewness	6.186	6.068
		0.742
Wage Kurtosis	64.110	74.826
		26.284
10th Percentile of Wages	0.315	0.261
		0.006
50th Percentile of Wages	0.898	0.969
		0.008
90th Percentile of Wages	3.833	3.750
		0.071
10/90 Wage Ratio	12.187	14.365
		0.447
10/50 Wage Ratio	2.854	3.714
		0.086
% Participation Predicted Correctly	0.722	0.720
	0.003	0.003
% Full Benefits Predicted Correctly	0.620	0.638
	0.005	0.004

As in the estimation, both the simulated and empirical values for "% Wage $= M$" include all those within 3 log points of the minimum wage; see Section 4.

Figure 10: Empirical and Simulated Benefit Levels



percentage points off, .58 in reality and .61 in the simulation. The simulation does well matching the number of informal workers at the minimum wage, although it does miss the fact that 1.9% of workers are clumped at the minimum wage with full benefits. Note that the percentage at the minimum wage actually includes a small window around M, accounting for the non-zero number of formal minimum wage workers in the simulation. Empirically, most workers at the minimum wage are informal, which fits the model. The simulation does have room for improvement in matching higher moments of the wage distribution as well as the wage quantiles, but is not far off for any value.

The last two rows of Table 6 move from the aggregate to the individual. They record how often the model's outcome for labor market participation or benefits accords with what the agent actually chose. 72% of work decisions are simulated correctly and 62% of benefit decisions. Considering that one can be right guessing a coin flip half of the time, 50% is presumably a good lower bound for confidence in the predictive power of any such model. Beyond that, the expected quality of the prediction depends on the variance of unobservables. As participation and benefits both have sizable unobserved components, it is not surprising that their prediction rates are in the 60's and 70's.

The next column over from these estimates compares two simulations to determine how often results coincide across simulations. These numbers are almost identical to the empirical results, with participation correctly inferred 72% of the time and benefits decisions correct 63% of the time. Thus the model predicts the empirical results as well as it predicts a sample of data drawn from the model. Although this can be true even if the model is false, it is reassuring that the data and the simulation conform closely in predicting individual, and not just aggregate, behavior.

In summary, the model fits the data very well. Although there are points of departure, the simulated distributions appear to to be much like the empirical distributions, the benefits distribution matches in its broad outline, and one can predict empirical individual outcomes with the same accuracy as one can predict simulated outcomes, suggesting that the proposed model is a reasonable approximation to the observed data.

7 Simulation

What would be the economic impact of lowering the minimum wage or decreased enforcement? A change in legislation or enforcement could affect employment, overall levels of formality, compensation, wages, and observed wage inequality. Unfortunately, the agent's optimization problem is sufficiently complex that the estimated parameters do not immediately reveal how policy change affects outcome variables. Instead, policy changes can be simulated from the model.

The simulation method is straightforward. The model parameters are drawn from Table 5 , the generalized specification that allows heterogeneity in evasion costs. The simulation first draws a sample of real workers from the

the *PNAD* survey. Using their observed covariates the simulation assigns unobservables to the workers based on the unobservables' distribution. This leads to an equilibrium set of work, wage and benefit decisions. One can then change a parameter of the model such as the minimum wage or the cost of evasion. The changes determine a new equilibrium set of work, wage, and benefits decisions which are log-differenced from the old equilibrium to determine changes that can be used to calculate elasticities.

Sections 7.1 and 7.2 consider two policy changes, a decrease in the minimum wage and a decrease in the evasion cost.

7.1 The Impact of Decreasing the Minimum Wage

As discussed in Section 3.4, if employment varies, the effect of a minimum wage change on wages or formality is ambiguous due to the compositional shifts involved. If employment is relatively constant, a lower minimum wage increases formality and payroll compliance; raises wages for informal workers well below the minimum; lowers the formal sector wage, but only among those near the minimum wage; and increases wage inequality. The magnitude of these effects and how they impact an observed wage distribution can be recovered with simulation.

The first column of Table 7 contains the equilibrium outcomes for the status quo policy in 1999. The middle column shows the effect of a .10 log decrease in the minimum wage.[29] Employment changed not at all, which is because the model estimated labor force participation to be almost completely inelastic. Since employment does not change, one can be guided by the theoretical comparative static results computed in Section 3.4 assuming stable employment.

Formality increases by 2.6%. Some of the increase is mechanical since dropping the minimum wage, even with no behavioral response, relabels some workers as formal. The fourth row shows the degree to which the formality

[29] Standard errors on the estimates are sufficiently small that, should an estimate be statistically insignificant, it would also be economically irrelevant, and so are excluded.

increase is behavioral. Lowering the minimum wage 10% causes a 1.9% rise in the number taking full benefits, suggesting an economically significant complementarity across types of informality.

This also shows that the rise in formality is not merely mechanical, some of it is due to agents choosing full benefits who previously were informal. These would be the agents who cannot quite be formal under the old regime. Since they don't fully value benefits, they discard some until their salary reaches the minimum wage. Under the new regime, these workers are above the minimum wage so any decrease in benefits must face the full cost of evasion. Faced with the evasion cost, the workers choose to remain at full benefits. In the next row, note that average benefits, $\tilde{\tau}_i$, move very little, suggesting that the principal change was from agents already close to full benefits, but not quite there.

The third row computes the average value of $\ln(\Delta_i)$, which is the cost of evasion for those who are informal. Note that the average is taken only over informal workers. The first column shows that the average informal worker receives 23 log points less solely due to their informality. Thus there is a 23% premium for being formal. This is only an average, as individual evasion costs vary widely. Lowering the minimum wage lowers these costs by 2 log points.

The remaining columns look at two measures of income, hourly compensation and the wage. The hourly compensation measure includes the value of benefits received, using the function $\psi(\cdot)$ and the the agent's own preference parameter, θ_i . The wage measure is straightforward. Hourly compensation averages about 3.3 across the population. Thus the agent would be indifferent between a wage of R$3.30 with no benefits and the current wage/benefits mix he is receiving. *On average*, a change in the minimum wage does not significantly change hourly compensation—effects are limited to the low wage population, so that the 10th percentile of the hourly compensation distribution rises about 7%, but the median and 90th percentiles are unaffected. This story is exactly replayed for wages, which on average change imperceptibly, but rise about 7% for the first decile, with no real change anywhere

Table 7: Simulated Policy Outcomes

Statistic	Simulation	$\tilde{M} - .1$	$\delta_M + .1$
% Employed	0.737	0.000	0.000
% Formal	0.485	0.026	-0.125
Average $\ln(\Delta_i)$ (Evasion Cost)	0.231	-0.020	-0.061
% At Legal Benefits Level	0.507	0.019	-0.119
Average Log Benefits, τ_i	0.530	0.008	-0.041
Hourly Compensation	3.290	0.001	0.009
10th Percentile of Hourly Compensation	0.355	0.068	0.134
50th Percentile of Hourly Compensation	1.773	0.000	0.013
90th Percentile of Hourly Compensation	7.557	0.000	0.005
Average Wage	1.660	0.000	0.036
10th Percentile of Wages	0.285	0.067	0.119
50th Percentile of Wages	0.977	0.000	0.047
90th Percentile of Wages	3.693	0.000	0.031
10/90 Wage Ratio	12.956	-0.067	-0.088
10/50 Wage Ratio	3.427	-0.067	-0.071

Policy change columns report the log change in the value due to the policy change.

Values are for 1999.

else. The results are to be expected given the comparative statics in Section 3.4. Average wage movements are ambiguous but the very low skilled see a rise in wages while the very high skilled are unaffected.

It is possible that minimum wage declines, coupled with employment loss, increase observed wage inequality Lee (1999). In this economy, however, employment loss is replaced by movement into an observable informal market, and the minimum wages clearly contributes to inequality. Thus both the 90–10 and the 50–10 ratios fall by about 7% with the drop in the minimum wage.

The results suggest that the minimum wage law encourages agents to be informal and that it increases the penalty to being low-skilled, which shows up both in the changing evasion cost and the higher wages among the very low skilled.

The plentiful data allows one to recover how policy affects specific demographic groups. Table 8 redoes the policy simulation by region and education to give a more refined sense of the effect of the minimum wage. The status quo outcomes are in Table 9 for reference. The minimum wage effects are almost nonexistent among the highest educated workers, but sometimes the effects are actually stronger among the middle-education groups than among the illiterate. These middle education ranges face a higher marginal evasion cost, δ_M, and a substantial number of workers still earn near the minimum wage.

The number of workers receiving full benefits moves strongly with minimum wage changes. Among Northern illiterate workers, a 10% decrease in the minimum wage *increases* full-benefit receipt by 9.1%, an elasticity of .91. This effect is weaker among the more educated and in the South, but for all but the most educated workers there are measurable and often strong complementarities between minimum wage compliance and non-wage benefits compliance.

Moving to compensation, in the North, the 10th percentile of illiterate workers' hourly compensation rises 4%, but rises 7% among the secondary–school educated. This suggests that the higher evasion costs take their toll on many educated workers. In the richer and more compliant South, the 10th percentile of compensation rises 7.6% for the illiterate, and drops off with education. Higher deciles are unaffected in all markets.

For wages, the story is slightly different. Here the 10th percentiles look similar, except for a 10% *drop* in wages among secondary–schooled Southern workers. Since compensation rose for all workers, it must be the case that these workers increased their benefits level when the minimum wage dropped. Thus the lower minimum wage gave them the opportunity to be formal by choosing full benefits, which they did. The possibility that minimum wage changes can cause some workers to have higher compensation but lower wages was discussed in Section 3.4. It leads to an ambiguous sign for the minimum wage effect on average informal wages.

This scenario is replayed at the 50th percentile of Northern illiterate workers. Although there is no sign of compensation falling for any worker, the median wage dropped 5% with the 10% decline in the minimum wage. Workers at the median are moving into the formal market, with a lower wage but equivalent or higher total compensation.

The last two columns report within–group wage inequality. As expected, inequality declines. In the Northern illiterate market the 50–10 wage gap declines a full 10%, suggesting an elasticity of 1 to minimum wage changes. Of course, the model reveals why this is somewhat illusory. Half the change came from workers at the median increasing their benefits at the expense of wages. A more poverty-relevant elasticity is how much the minimum wage decline increases compensation among the least productive. This compensation elasticity ranges from 0 for the highly educated to -.76 for Illiterate workers in the South. This suggests that minimum wage declines can result in large welfare improvements among some very poor workers.

These minimum wage elasticities are fascinating. The theory and evidence presented, which is consistent with past work, suggest that raising the minimum wage not only fails to raise compensation for many workers, it actually *depresses* wages among low-skilled workers by a percentage approaching the percentage of the minimum wage increase. It also moves workers into the informal sector by encouraging abandonment of payroll taxes and other non-wage benefits, once again with an elasticity approaching unity for some workers.

Table 8: Changes from a 10% Decrease in the Minimum Wage by Region and Education

Statistic	North				South			
	Illiterate	Elementary	Secondary	Post-Second	Illiterate	Elementary	Secondary	Post-Second
% Employed	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
% Formal	0.142	0.114	0.058	0.013	0.071	0.035	0.020	0.005
Average $\ln(\Delta_i)$ (Evasion Cost)	-0.020	-0.019	-0.024	-0.014	-0.026	-0.020	-0.023	-0.009
% At Legal Benefits Level	0.091	0.079	0.032	0.008	0.066	0.025	0.014	0.003
Average Log Benefits, τ_i	0.015	0.015	0.013	0.003	0.017	0.009	0.008	0.001
Hourly Compensation	0.007	0.005	0.004	0.000	0.005	0.002	0.002	0.000
10th Percentile of Hourly Compensation	0.040	0.053	0.067	0.008	0.076	0.054	0.038	0.000
50th Percentile of Hourly Compensation	0.004	0.008	0.000	0.000	0.000	0.000	0.000	0.000
90th Percentile of Hourly Compensation	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Average Wage	0.000	-0.001	0.000	0.000	-0.001	0.000	0.000	0.000
10th Percentile of Wages	0.040	0.051	0.075	0.000	0.071	0.079	-0.092	0.000
50th Percentile of Wages	-0.051	0.000	-0.001	0.000	0.000	0.000	0.000	0.000
90th Percentile of Wages	0.000	0.000	0.000	0.000	0.000	-0.001	0.000	0.000
10/90 Wage Ratio	-0.040	-0.052	-0.075	0.000	-0.071	-0.080	0.092	0.000
10/50 Wage Ratio	-0.091	-0.052	-0.076	0.000	-0.071	-0.079	0.092	0.000

Columns report the log change in the value due to the policy change.

Table 9: Simulated Outcome by Region and Education

Statistic	North				South			
	Illiterate	Elementary	Secondary	Post-Second	Illiterate	Elementary	Secondary	Post-Second
% Employed	0.778	0.699	0.636	0.728	0.798	0.786	0.730	0.767
% Formal	0.095	0.196	0.349	0.642	0.305	0.506	0.584	0.745
Average $\ln(\Delta_i)$ (Evasion Cost)	0.292	0.281	0.276	0.151	0.304	0.220	0.212	0.121
% At Legal Benefits Level	0.119	0.221	0.387	0.656	0.329	0.531	0.610	0.753
Average Log Benefits, τ_i	0.254	0.348	0.476	0.629	0.441	0.554	0.591	0.656
Hourly Compensation	0.802	1.092	1.697	5.143	1.321	2.399	2.892	7.176
10th Percentile of Hourly Compensation	0.141	0.165	0.241	0.948	0.212	0.487	0.561	1.355
50th Percentile of Hourly Compensation	0.581	0.760	1.177	3.094	0.941	1.713	2.058	4.609
90th Percentile of Hourly Compensation	1.714	2.302	3.595	11.046	2.919	4.990	6.129	15.402
Average Wage	0.558	0.707	0.936	2.480	0.761	1.225	1.487	3.338
10th Percentile of Wages	0.126	0.150	0.185	0.509	0.177	0.351	0.424	0.710
50th Percentile of Wages	0.427	0.519	0.679	1.575	0.563	0.915	1.091	2.206
90th Percentile of Wages	1.114	1.450	1.902	5.126	1.556	2.470	3.059	7.108
10/90 Wage Ratio	8.828	9.681	10.293	10.079	8.813	7.049	7.218	10.010
10/50 Wage Ratio	3.388	3.464	3.677	3.097	3.187	2.610	2.573	3.107

7.2 Decreasing the Evasion Cost

This section considers the effect of decreasing the enforcement of current laws. This is parameterized as a uniform .1 decrease in the marginal evasion cost, which is done by increasing δ_{Mi} by .1 for each agent. Since δ_{Mi} is always below .1, there are no corner difficulties in this choice of simulation.

The last column of Table 7 gives simulation results. Once again, employment is unaffected. Unsurprisingly, formality takes a hard hit, with a 12.5% decrease. This is largely due to an almost 12% decline in those taking full benefits. The cost paid for informality falls 6 log points, taking it from 23 down to 17. Since the policy reduces evasion costs by about one fourth, it is unsurprising that evasion costs fell by about one fourth. Hourly compensation was not strongly affected on average, but among the lowest paid, the effect on wages is dramatic—a 13 log point increase. Wages show universal increases as agents transfer more benefits into cash payments. So while the bottom decile increases wages by 12%, even the top decile cashes out benefits for a 3% rise in wages. From these deciles, one can generate inequality ratios, which show a 9% decline in the 90–10 wage gap and a 7% decline in the 50–10 gap. These gains are "real" in the sense that they are not artifacts of changing forms of compensation. In fact, the hourly compensation inequality fell by slightly more than the wage inequality.

For reference, Table 10 breaks out the policy effects by region and education. The results are consistent with the national results. Formality declines steeply and so do average evasion costs. Hourly compensation rises mosts among the 10th percentile, with some of the gains very large. In the North, the 10th percentile sees a 20% compensation increase for all but the most educated. In the South, the jump is comparably large for illiterate workers, but drops off sharply for educated workers. In cases where the 10th percentile effect is strong, the median wages also rise slightly. The net results indicate a strong drop in wage inequality. Thus a decrease in evasion costs would have strong positive effects on the low-wage population, at the cost of decreasing compliance with payroll taxation and encouraging informality.

Table 10: Changes from a .1 Decrease in the Marginal Evasion Cost δ_M by Region and Education

Statistic	North				South			
	Illiterate	Elementary	Secondary	Post-Second	Illiterate	Elementary	Secondary	Post-Second
% Employed	0.001	0.001	0.001	0.001	0.000	0.000	0.000	0.000
% Formal	-0.498	-0.320	-0.130	-0.108	-0.369	-0.158	-0.129	-0.077
Average $\ln(\Delta_i)$ (Evasion Cost)	-0.099	-0.087	-0.078	-0.019	-0.088	-0.052	-0.049	-0.004
% At Legal Benefits Level	-0.375	-0.277	-0.117	-0.106	-0.336	-0.150	-0.123	-0.076
Average Log Benefits, τ_i	-0.050	-0.051	-0.040	-0.039	-0.062	-0.047	-0.040	-0.030
Hourly Compensation	0.050	0.035	0.019	0.006	0.026	0.012	0.009	0.004
10th Percentile of Hourly Compensation	0.234	0.219	0.197	0.011	0.210	0.081	0.054	0.006
50th Percentile of Hourly Compensation	0.048	0.038	0.016	0.007	0.025	0.007	0.009	0.006
90th Percentile of Hourly Compensation	0.035	0.020	0.005	0.000	0.000	0.010	0.003	0.004
Average Wage	0.116	0.093	0.055	0.027	0.080	0.048	0.037	0.019
10th Percentile of Wages	0.226	0.202	0.187	0.040	0.179	0.088	0.008	0.025
50th Percentile of Wages	0.047	0.086	0.048	0.034	0.064	0.046	0.030	0.018
90th Percentile of Wages	0.118	0.085	0.069	0.006	0.086	0.040	0.038	0.021
10/90 Wage Ratio	-0.108	-0.117	-0.119	-0.033	-0.094	-0.048	0.030	-0.004
10/50 Wage Ratio	-0.179	-0.116	-0.139	-0.006	-0.116	-0.042	0.022	-0.007

Columns report the log change in the value due to the policy change.

Drawing together the results from the two simulations, minimum wage laws drive down informal wages, exacerbate wage inequality, and discourage payroll compliance. Among some groups, these effects can be substantial. Decreasing the cost of illegality is obviously a boon for illegal workers, it also, as expected, lowers compliance with payroll laws, thus encouraging informality.

8 Conclusions

Section 8.1 considers some caveats and future extensions and Section 8.2 concludes.

8.1 Caveats and Extensions

There are many ways in which the model presented might be expanded. Several of these are considered below.

8.1.1 Self Employment

The model treats the self-employed identically to employees. This obviously is not a full solution. Self-employed workers are an important part of the informal market, and they do face laws that they may choose to evade, such as social security taxes. They also have a host of additional regulations that employees would not face, which they could choose to evade. In this case, the non-wage benefits become a very different set of regulations than for the employed, but which also could be traded off for higher income should the agent be willing to evade them. Since the model allows for heterogeneity in evasion costs and preferences for benefits, the distribution of those variables is estimated as an aggregate of the costs and preferences of the employed and self-employed.

The other difficulty is how to treat wages below the minimum wage for the self-employed. This is not illegal, and yet it may often be a reaction to the inability of the agent to find legal employment. Since informal agents are observed both as employees and self-employed, the costs between the two states must be comparable, or there must be some unobserved heterogeneity across agents. This paper assumes that in equilibrium the self-employed face higher costs of doing business, whether due to regulation or other costs associated with small businesses, and that these costs are estimated by the Δ function. If the extra costs of self-employed business are systematically lower than evasion costs are , this is partially captured by the heterogeneity in Δ. More extensive heterogeneity in productivity could be entertained, with agents choosing whether or not to be self-employed based on their individual productivity in each area, and is the subject of future research.

8.1.2 Endogenous Policy Variables

The minimum wage and current enforcement efforts are both determined by policymakers with some set of objectives in mind. These variables are treated as exogenous to the model, where the extensive dummy variables representing prices capture interactions between the macroeconomic environment and policy decisions. The fact that such an extensive set of dummies can be included reemphasizes the source of variation in the model as being cross-sectional, as opposed to being from time series variation in the minimum wage. Obviously this approach has its pitfalls, but it is much less vulnerable (though not immune) to concerns about minimum wage endogeneity than a typical time-series model.

One may also consider enforcement to be a policy lever that is manipulated over time to affect the size of the informal market. As shown in the Appendix, it is possible to estimate year-specific evasion costs. One could also allow costs to differ between the minimum wage and non-wage benefits. Thus one could, in principle, use these estimated evasion costs to estimate a political economy model with enforcement as an outcome variable, with variation across years or regions. Obviously, this would be difficult to accomplish with only time-series evidence.

8.1.3 Employment and General Equilibrium Price Effects

The estimation finds that there are no employment effects to regulation and enforcement changes and, as noted in the Appendix, the available time-series data cannot reject the hypothesis that there are no price effects. The two findings are not unrelated and some discussion is in order.

The results on employment are entirely due to the fact that the estimation found employment to be insensitive to price movements, which occur principally across years. But prices may suffer from measurement error in the price index. It may be the case that there really are employment effects to the minimum wage, but the data are inadequate for finding them due to an attenuation bias from measurement error.

The current simulation holds the price vector fixed. As reported in the Appendix, this is due to the fact that the available time-series is uninformative about how prices move with the minimum wage. But if a policy change lowers the supply of labor then it will raise prices based on the elasticity of labor demand—so minimum wage regulation and evasion costs prop up the formal sector prices. Price effects are likely to be more relevant in the illiterate market, where labor law violation is relevant to much of the work force, as opposed to the well-educated workers where very little of the labor force is below the minimum wage. Regardless, these price effects would mitigate some of the damage of labor regulation, and they imply that decreasing regulation does not just benefit low wage workers, it also transfers wealth from high productivity to low productivity workers as the barriers to entry into the formal market disappear.

Of course, since the results imply that there is no employment effect to the minimum wage, there is no labor supply response to the minimum wage. This is perfectly consistent with an assumption of no price changes. So if one believes there are price effects, there must also be employment effects, and *vice versa*. Further, these findings are the two which most clearly rely upon time-series variation. Thus if these two findings are suspect, one should perhaps be even more wary of results from standard techniques that are dependent principally on time-series variation for identification.

If more data were available on firms, which would be difficult, one could perhaps model and estimate the demand side responses to the minimum wage. In an ideal world, such a model would allow estimation of market power on the demand side, to determine if monopsony power is sufficiently important to affect the policy implications of minimum wage and benefit laws.

8.1.4 Women and Family Dynamics

Women, whose employment elasticity may be different and for whom wages are lower, may have a different response to labor legislation and enforcement. Women also tend to work in different occupations, thus evasion cost differences across occupations, which are ignored here, might become an important reason for differences between men and women. Estimating the model for women would also be a stepping stone to a model that considers the household labor supply problem as a whole, and not just as disparate individuals.

The intra-household problems are difficult to unravel, but it may be that changing the relative compensation of men and women in the household could have important effects on intra-household allocation. A family-level model could allow one to determine how households allocate labor across formal and informal employment. It may be the case that households move together in and out of formality if, for example, informal employment tends to be done at the family level. Or it may be important to have one formal employee to provide benefits for the household, but not so important that secondary earners be formal, as the benefits are redundant.

8.1.5 Dynamics and Distributions

The estimates rely upon a specific model of how the minimum wage affects the economy coupled with assumptions about unobserved distributions of structural error terms. The distributional assumptions could be relaxed or modified to provide a better fit to the data. It would also be worth knowing if this methodology reports similar evasion costs across countries, and if the evasion costs can be related to observed enforcement differences over time or across countries.

The model does not attempt to model the dynamic process that causes workers to move between jobs and firms to respond to changes in the minimum wage. It may be that there are important lags in response to minimum wage changes. This model treats those lags as being shorter than one year (usually the time between the setting of the wage in May and the survey in September). Developing a model with some element of adjustment costs could prove fruitful.

8.2 Conclusion

In summary:

- Mandated non-wage benefits and the minimum wage law have almost no effect on employment, but do encourage informality and lower total compensation.
- Lower minimum wages encourage workers to formalize their benefits: a 10% decrease in the minimum wage *increases* by 1.9% the number of workers paying all payroll taxes. Among Northern illiterate workers the increase is 9%, implying strong complementarities across types of informality.
- Controlling for productivity and non-wage benefits, formal workers get an average 23% wage premium.
- Although marginal evasion costs rise with education, poorly educated workers are far less likely to be able to meet the minimum wage and benefit standards. Thus the average formality premium is highest among the least educated.

- Lower minimum wages and laxer enforcement of the law both increase wages among the low skilled and decrease wage inequality, which is in contrast to results in the U.S. that decreases in the minimum wage increase inequality.

These results come from using cross-sectional, as opposed to time-series, variation to identify labor market distortions. Although time-series variation can be an excellent tool in many cases, when the series are short, the variation is not very informative. This approach represents a useful alternative in cases where cross-sectional data is comparatively plentiful.

The minimum wage and non-wage benefits have important effects on the economy by pushing workers into informality. Evasion of the two laws is complementary, so that the evasion of one regulation increases evasion of the other. This effect is worth keeping in mind when considering the proper level for wage and non-wage minima. Informal workers, who make up a huge chunk of the work force, receive lower compensation then they would were the regulations loosened to allow the workers to become formal. Thus the regulations segment the market in a way that is harmful to the least-skilled workers.

A Computational Algorithm

This section describes the algorithm used to compute probabilities, given that they require numeric simulation. [30] For this section, let L_x be the set over which x is integrated for the given worker. Thus if θ is to be integrated over the range $[0, \ln B - \delta_m]$, this range becomes the set L_θ.

For a non-worker, draw a vector of individual parameters, $\{t, \theta, \delta\}$ and compute w^* and τ^*. The probability distributions of all the random parameters

[30] Train (2003) provides an accessible discussion of numerical simulation methods in discrete choice problems.

are given in Section (5.1). Compute the value

$$F_\zeta = \int_{\zeta < \ln(1+n) - \ln(1+n+\psi(w^*,\tau^*))} f_\zeta(\zeta | t, \theta, \delta).$$

This value becomes one repetition. The exercise is repeated and all the average of the computed values provides a consistent estimate of the probability the agent chooses not to work.

For workers, the algorithm differs slightly depending on whether the wage is above, at, or below, the minimum wage. First consider workers above the minimum wage:

1. Draw δ from $f_\delta(\delta)$
2. Draw θ from $f_\theta(\theta | \theta \in L_\theta)$. If L_θ is empty (which can happen for some values of δ), record a value of 0 and go to the next iteration.
3. Compute:
$$(1 - F_\zeta) \cdot f_{\ln t}(\ln t | \theta, \delta)$$
where F_ζ is defined above.
4. Multiply the above by $P(\theta \in L_\theta)$, to account for the importance sampling in step 2, then record the value and make a new draw.

After a sufficient number of iterations, the desired probability is the average of all the computed values. Next consider workers below the minimum wage.

1. Draw θ from $f(\theta | \theta \in L_\theta)$. Note that for these workers, the set L_θ does not depend on δ.
2. Draw δ from $f_\delta(\delta | \delta \in L_\delta)$
3. The above draws determine a unique value of t that results in the observed wage, so compute:
$$(1 - F_\zeta) \cdot f_{\ln t}(\ln t | \theta, \delta) \cdot (1 + \delta_M).$$

4. Multiply the above by $P(\theta \in L_\theta, \delta \in L_\delta)$, to account for the importance sampling in steps 1 and 2, then record the value and make a new draw. Note that the joint probability above is easily computed as a conditional probability:$P(\delta \in L_\delta | \theta \in L_\theta) \cdot P(\theta \in L_\theta)$.

Once again, the desired probability is the average of all the computed values.

Lastly, consider workers clumped at the minimum wage without full benefits.[31] The clumping at the minimum wage means that one cannot recover a unique productivity value given θ and δ. This causes a slight change in the algorithm:

1. Draw θ from $f(\theta | \theta \in L_\theta)$. Once again, L_θ does not depend on δ.
2. Draw δ from $f_\delta(\cdot | \delta \in L_\delta)$.
3. The possible t given θ and δ is not unique for these workers, so draw $t \in L_t$ and compute:
$$1 - F_\zeta$$
4. Multiply the above by $P(\theta \in L_\theta, \delta \in L_\delta, t \in L_t)$ to account for the importance sampling in steps 1, 2, and 3, then record the value and make a new draw. Note that the joint probability can once again be computed as a conditional probability.

Since these algorithms cover all possible states, one can compute the probability of observing any agent, and therefore compute the log-likelihood function.

B Price Effects

The structural model uses a set of dummies to capture the changing prices faced by workers. One may be concerned that these formal sector prices

[31] Although the model does not predict clumping at the minimum wage for those with full benefits, such clumping does occur. Full benefit minimum wage workers are handled in precisely the same fashion as workers above the minimum wage.

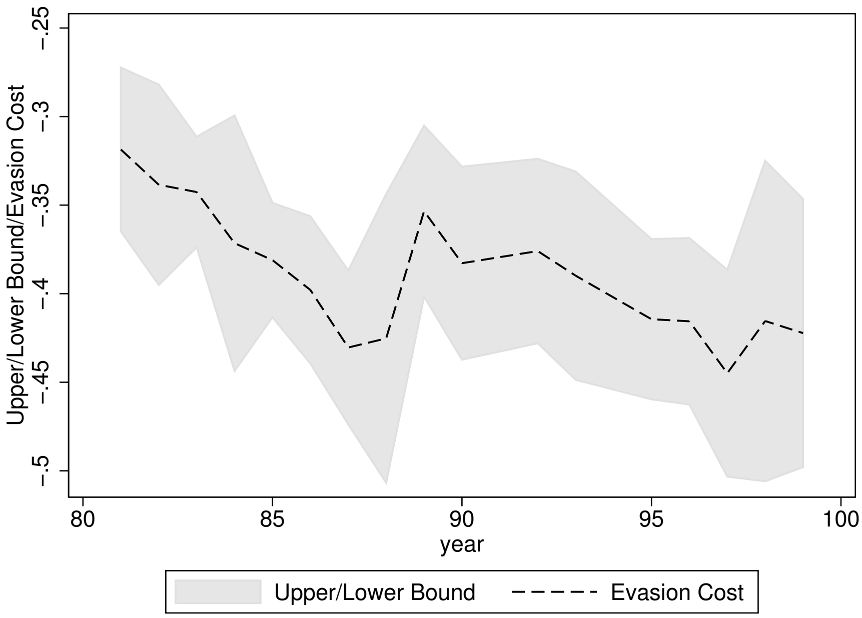
respond to minimum wages or other changes. Unfortunately this is very difficult to recover. Estimating how prices change with the minimum wage is hard enough— given the very short time period involved. Estimating how prices move with a change in benefits is even harder, given the lack of variation in benefits. One could, with the model presented, estimate year—specific evasion costs, and see how these move with prices. But this is asking a great deal of a very limited time-series.

Table 11 reports on the elasticity of formal sector prices to the minimum wage, where prices are the recovered dummy variables from the previous estimation. Additional regressions control for changes in education and regional differences, an unobserved time trend, and business cycle phenomenon such as the log of GDP and the log of inflation. Additional specifications check for differences across markets (either by region or education) in responses to the minimum wage. The results show that there is a strong correlation between prices and the minimum wage, but that controlling for a time trend and business cycle effects, the estimate is not significantly different from 0.

To some extent, this insignificance is because of the imprecision of the estimation; the standard error of about .2 is quite large. But note that, if there are unobserved errors in the price index used, the error affects both the minimum wage and the price vector, biasing results upwards. This may be particularly a concern given that including the log inflation rate, which is likely to be correlated with measurement error in the price index, is very important in lowering the estimated elasticity of prices to the minimum wage. Because of this potential measurement bias, the simulations concentrate on the case where formal sector prices are not affected by the minimum wage.

Columns 4-8 redo the regressions allowing for varying effects across education and region. An alternative identifying assumption in the presence of price index error is that the most educated market's formal sector price is essentially unaffected by the minimum wage, since it impacts so few of that sector's workers. The coefficient on this 'control' group would then be an estimate of the measurement error, and one can subtract this value from the other parameters to get an estimate of how prices are affected by the minimum wage. But the estimated standard errors are once again so large as to eliminate all confidence in using them for identification.

Figure 11: δ_M Evasion Costs by Year



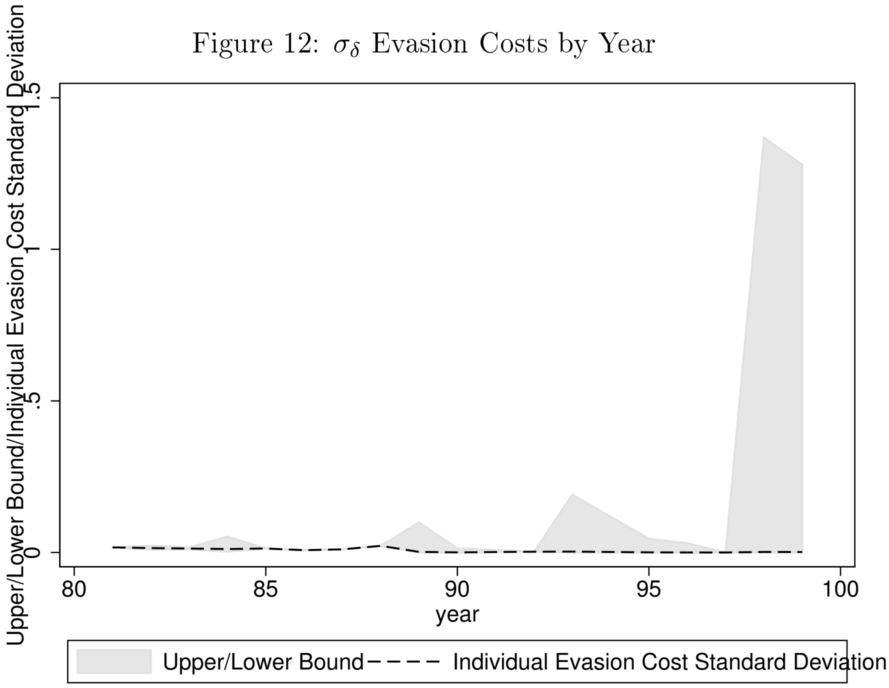
One can re-estimate the model in Section 6.1 by parameterizing evasion costs as solely a function of the year:

$$\delta_{Mi} = \delta^0_{Mt}$$

$$\sigma_{\delta i} = \sigma^0_{\delta t}$$

where the effect can vary arbitrarily by year. These coefficients are plotted with confidence intervals in Figures 11 and 12. There may be real variation across years, but it is swamped by the uncertainty of the estimates. Note that, on average across all agents, the individual fixed cost of evasion is basically 0 with huge standard errors resulting from the weakened identification, but that there remains a fairly substantial tax on informality from δ_M. There appears to be some consistent trending over time, with a jump

Figure 12: σ_δ Evasion Costs by Year



around the constitutional changes in 1988-1989. The large sampling error rules out using these parameters as regressors for price as there is very little informative variation.

Given this lack of information, I assume that there are no price effects from changes in evasion costs. It is likely that *large* changes in evasion costs would cause some distortion to the price vector. Thus the simulation results are subject to the caveat that they are only drawn from a partial equilibrium analysis, which could in principal be expanded given more data on firm behavior.

Table 11: Formal Sector Prices as a Function of the Minimum Wage

Covariates	Coefficient Estimates						
	1	2	3	4	5	6	7
Minimum Wage	0.781	0.599	0.211	0.951	0.86	0.381	0.29
	[0.165]**	[0.180]**	[0.200]	[0.290]**	[0.182]**	[0.270]	[0.175]
Year		-0.092	-0.262			-0.262	-0.262
		[0.039]*	[0.047]**			[0.040]**	[0.033]**
GDP			1.79			1.79	1.79
			[0.474]**			[0.395]**	[0.334]**
Inflation			-0.059			-0.059	-0.059
			[0.022]**			[0.018]**	[0.016]**
South					0.167		0.167
					[0.220]		[0.177]
South*Minimum Wage					-0.157		-0.157
					[0.258]		[0.208]
Elementary*Minimum Wage				-0.187		-0.187	
				[0.410]		[0.348]	
Secondary*Minimum Wage				-0.192		-0.192	
				[0.410]		[0.348]	
Post-Secondary*Minimum Wage				-0.301		-0.301	
				[0.410]		[0.348]	
Constant	0.719	0.646	-15.129	0.653	0.636	-15.195	-15.213
	[0.140]**	[0.142]**	[4.119]**	[0.247]**	[0.155]**	[3.441]**	[2.907]**
Education Dummies	No	No	No	Yes	No	Yes	No
Observations	136	136	136	136	136	136	136
R-squared	0.14	0.18	0.33	0.37	0.48	0.56	0.67

Standard errors in parentheses * significant at 5%; ** significant at 1%. Dependent variable is formal sector price—π_F

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