Productivity, Non-Compliance and the Minimum Wage

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Abstract

Many informal firms in developing countries would not be viable if they were to comply with the minimum wage law. This means the authorities have an incentive to turn a blind eye to non-enforcement in a substantial share of firms. We also survey enforcement mechanisms for the minimum wage across developing countries and find that worker complaints are an important element in determining whether firms will be inspected for non-compliance or not. We develop a theoretical monopsony model which rationalises the stylised facts we observe. For a given minimum wage, the government can choose a level of enforcement and penalties for non-compliance such that employment will not fall for any optimising firm, irrespective of their productivity. Low productivity firm's optimal choice of employment and wage will be unaffected by the introduction of the minimum wage. High productivity firms comply so that wage and employment effects are non-negative for these firms.

Keywords: Minimum wage, productivity, non-compliance, informal sector, firms.

JEL Classification: D24; J31; O17

1. Introduction

For some entrepreneurs, who manage small informal low productivity firms in developing countries, not-complying with the regulatory structure implied by being a formal firm, including complying with the minimum wage is a matter of survival.[1] Small informal firms in developing countries account for up to half of total income (La Porta and Shleifer, 2008; Schneider, 2005) and represent a large share of employment.[2] Furthermore, the empirical literature on compliance with minimum wage shows that large proportions of workers are paid less than the minimum wage in developing countries.[3] For instance, infractions of the minimum wage law in 2000 and 2001 were fourth in

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[1]Most empirical studies confirm that informal firms are on average less productive compared with formal firms (La Porta and Shleifer, 2014; Benjamin and Mbaye, 2012).

[2]In the sample of 22 countries we use in our empirical analysis, the informal sector is estimated at almost 75% of the non-agricultural workforce, on average, and it ranges from 48% in Argentina to more than 90% in Burkina Faso, Cambodia and Ivory Coast (source: ILO).

[3]See, for instance, Strobl and Walsh (2003) for Trinidad and Tobago, Strobl and Walsh (2016) for Thailand, Gindling and Terrell (2005, 2009) for Costa Rica and Honduras, and Neumark et al. (2006) for Brazil.

importance among the fourteen infractions of the labour law in Costa Rica (Gindling and Terrell, 2007). One reason for widespread non-compliance in developing countries is that enforcement is relatively weak compared to that in developed countries (Maloney and Mendez, 2004; Kanbur and Ronconi, 2018; Gindling et al., 2015; Ham, 2018). According to von Richthofen (2002), the prevalence of non-compliance with the minimum wage is exacerbated by unwillingness to complain, for fear of losing one's job. Danziger (2010) suggests, some underpaid workers do not file a complaint, either out of ignorance or to avoid reprisal by the employer.

Despite this, the literature tends to focus on compliance/non-compliance with the minimum wage as a matter of choice rather than survival. In this article, we address this issue by accounting for two important stylised facts. First, the types of workers and firms not complying with the law are predictable, suggesting that there is an element of what Basu et al. (2010) termed "turning a blind eye" by the enforcement authorities at play here. The empirical evidence we present later in the article, from surveys of informal firms by the World Bank shows that - for a range of developing countries - over one third of informal firms have output per worker which is less than the minimum wage. A more realistic measure of viability would certainly lead to substantially higher shares of firms that could not pay the minimum wage and survive. Second, enforcement of minimum wage legislation depends on worker complaints. Our survey of enforcement regimes documented below provides evidence for this second stylised fact. We posit that when minimum wage enforcement inspections are triggered by worker complaints, enforcement is targeted away from low productivity firms where workers fearing job loss have little incentive to complain. In higher productivity firms where enforcement of the minimum wage will not reduce employment workers can only gain from complaining, making enforcement more likely.

The article has three main parts: (i) an analysis of firm-level cross-country data to survey the ratio of the minimum wage to firms' productivity level; (ii) a survey of minimum wage enforcement regimes across countries which reveals that worker complaints is the primary determinant of minimum wage inspections in many countries; and (iii) a theoretical model where enforcement based on worker complaints allows the authorities to target enforcement on firms that are productive enough to afford to pay the minimum wage and guarantees no reduction in employment. The model we outline below demonstrates these results. We acknowledge that some of the assumptions we impose in the interest of describing the mechanisms driving the results are likely to introduce a lot of structure. For example, we assume that (i) workers know the true productivity of the firm employing them and (ii) workers who complain to the authorities if they are paid less than the minimum wage

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will never be punished by their employer for doing so. Clearly, these assumptions can be shown not to be true in many cases. We will argue though that the mechanisms we demonstrate will very likely hold for many workers and firms, but perhaps not for all. In this regard, we acknowledge that workers may not know the exact productivity of their firm. However, for many workers in high or low productivity firms, the signal of productivity they have will be sufficiently strong for the worker to know what the consequences of complaints that force the firm to comply with the minimum wage will be for the firm and in turn for the employees' employment prospects. We know also that there are cases where workers may fear complaining about underpayment of wages for fear of reprisal and indeed this may be a deliberate policy for some firms. Again, we will argue that it is likely that, for many of the firms where workers would wish to complain, committing to a strategy of punishing workers who complain could be very costly.

We will refer to "informal" and "formal" firms throughout the article. An informal firm is one that is not registered with the government and we infer from this is not paying tax and complying with all forms of regulation. The main regulation of concern in this article is compliance with the minimum wage. Clearly, formality induces many costs (like regulation costs, payroll and other taxes) but provides potentially lower capital costs and an access to government services. Many of these costs and benefits will affect the firms labour demand curve but will not directly affect the workers welfare. However, compliance with worker social security/tax deductions and the minimum wage are different since they affect labour supply. It is also true that many formal firms tare non-compliant with the minimum wage. That is, different firms would comply with different parts of the regulatory structure and the enforcement of different aspects of government regulations may not be fully integrated, which makes it more difficult to model a firm with multiple regulations. Given that our aim in this article is to address the issue of non-compliance with the minimum wage, the only government regulation we include explicitly in the theoretical model is non-compliance with the minimum wage. We note here that the firm level data we use to establish that many informal firms in particular are likely to be non-compliant with the minimum wage does not have direct evidence on wages showing that these firms are non-compliant. Rather we infer that firms whose output per worker is so low that they could not pay the minimum wage and remain viable are very likely to be non-compliant.

We will outline a monopsonistic model which is similar to Basu et al. (2010), BCK from now on. A key difference with BCK is that we assume that the probability that the firm will be inspected depends on worker complaints rather than being a constant. Another difference is that

while the government's welfare function depends on both inequality and employment in the BCK model, the model we present below implicitly assumes that the authorities place a high weight on employment loss in their welfare function, i.e. the authorities prefer not to enforce the minimum wage in any firm where it will reduce employment. We model the workers incentive to complain under the assumption that workers know their employer's productivity. These assumptions allow us to solve for a simple tractable equilibrium that demonstrates how endogenous enforcement can be used to target enforcement at firms who if caught, will pay the minimum wage without reducing employment. The model we present is not the first to endogenise enforcement, but to our knowledge it is the first to explore the possibility that an enforcement regime based on worker complaints can be used to target enforcement towards high productivity firms.

In contrast to the model we outline below, most models looking at non-compliance and the minimum wage assume a constant probability of detection for non-compliant firms. Ashenfelter and Smith (1979) in their classic paper document widespread non-compliance with the minimum wage for the US. They outline a theoretical model of non-compliance with a fixed penalty for a firm caught in non-compliance and a fixed random probability of being caught if non-complying and also show that most US inspections were complaints based. Grenier (1982) shows that, when the penalty for detection is proportional to underpaid wages rather than fixed, the probability of compliance is higher the further is the wage from the market wage and the smaller is the absolute value of the elasticity of demand, the opposite of the predictions of Ashenfelter and Smith (1979). Chang and Ehrlich (1985) make the penalty suffered by a non-complying firm a constant multiple of the underpayment of wages by firms and show that if this constant is less than unity, non-compliance will be profitable. They show that if the expected wage under non-compliance is higher than the minimum wage (including the penalty if caught), then there will be full compliance. Yaniv (1994) develops a model which shows that a bigger deviation between the minimum wage and the competitive wage may reduce the workers incentive to complain the sooner the worker expects the minimum wage to be enforced. To our knowledge, the first model with endogenous enforcement of the minimum wage is Yaniv (2001), which allows the probability of being detected to increase with the number of non-compliant workers to reflect the likelihood that more non-compliant workers means more complaints. This leads to the notable result that risk averse employers who can choose to hire both compliant and non-compliant workers simultaneously, will reduce employment by the same amount irrespective of the level of compliance. A more recent paper by Bhorat et al. (2015) does not restrict non-compliant firms to paying the competitive wage. As in Yaniv (2001), the employment

level is independent of the level of compliance; however the wage paid in a non-compliant firm depends positively on the productivity of the firm and on the intensity of monitoring and the size of the penalty as a percentage of the underpaid wage bill.

An interesting implication of our model is that, although we endogenise the enforcement mechanism, it turns out that once a firm has decided whether to comply or not, the firm's choice of wage and employment is much simpler than in most models of compliance. This is because when workers in high-productivity firms are paid less than the minimum wage, they would certainly complain and cause an inspection. Knowing this, the firms will comply and behave like a minimum wage firm in a simple model with full compliance. By contrast, Workers in low productivity firms that would close if forced to comply, will not complain, so that the firm can safely ignore the minimum wage in equilibrium and behave like a firm where there is no minimum wage. In terms of firm behaviour and compliance with the minimum wage, our model suggests there will be two categories of firms. High-productivity firms will always comply since they are sure to be caught in non-compliance and low-productivity firms will not comply, safe in the knowledge that they are unlikely to be caught given that their workers will not complain. Furthermore, the policy implication of increasing enforcement depends on the nature of the enforcement. If, as our data analysis suggests, a substantial percentage of informal firms could not be viable at the minimum wage, an increase in random enforcement may have large negative employment effects. Devoting more resources to investigating and enforcing worker based complaints on the other hand are more likely to raise compliance and wages in higher productivity firms but have less impact on lower productivity firms where workers have little incentive to complain. The policy implications of increasing penalties for non-compliance are also very different. In a model with random inspections where we do not explicitly consider firms who would not be viable at the minimum wage, higher penalties typically raise compliance for some firms by raising the expected profit of compliance relative to non-compliance. For a complaints based enforcement system, where there is a large group of firms who could not be viable at the minimum wage, higher penalties are more likely to reduce compliance with the minimum wage.

The remainder of this article is structured as follows. The next section presents the data and some key stylized facts. In section 3 we survey inspection arrangements and penalties for non-compliance in place across a large group of developing countries. We develop the theoretical model in section 4. The final section concludes.

2. Facts about productivity, minimum wage and informality

In this section, we rely on firm data to give empirical evidence on productivity, minimum wage, employment and informality in a number of developing countries. We show that average productivity for a sizeable share of firms is lower than the minimum wage and therefore these firms could not survive if forced to pay the legal minimum wage. Low productivity firms, which employ a large share of workers, are more likely to be in the informal sector and to pay lower wages on average.

2.1. Data description and productivity criterion

We use firm-level data from two sets of standardised surveys conducted since 2002 by the World Bank and administered to business owners and senior managers of private sector establishments:[4] (i) the Informal Enterprise Surveys (IFS) which collect data on non-registered informal firms in a number of developing countries with a large informal sector and (ii) the Enterprise Surveys (ES) which interview registered formal firms from several countries around the world. In each country, businesses located in the cities or regions of major economic activity are interviewed. The two sets of surveys cover firms with manufacturing or services as their main activity and give further information on firms' general characteristics, infrastructure, finance, labour and assets.

For the IFS, we consider informal firms from 22 developing countries who have adopted minimum wage legislation: Angola, Argentina, Botswana, Burkina Faso, Cambodia, Cameroon, Congo, Ivory Coast, Ghana, Guatemala, Kenya, Lao, Madagascar, Mali, Mauritius, Mozambique, Nepal, Niger, Peru, Rwanda, Zambia and Zimbabwe.[5] The earliest available data are from 2005 for Niger and the latest from 2019-2020 for Zambia. To select informal firms, the IFS rely on the respondent's answer to whether the firm is registered with any agency of the central government. Thus, the selected firms could still either comply or not with the legal minimum wage. The use of ES for the same pool of IFS developing countries enables us to make comparative statements of both formal and informal firms in every country. The data we use cover 15,952 firms with non-missing information among which 6,045 are informal.[6] The ES sample covers a total of 9,907 firms. The sample of informal (formal) firms is composed of observations, ranging between 62 (51) and 629 (962) firms per country.

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[4]Firms with full government or state ownership are not eligible to participate in a survey.

[5]The IFS cover a total of 27 countries. However, there is no minimum wage legislation in Afghanistan, Cape Verde, Myanmar and Somalia at the year of the survey. The World Bank also carried out a survey on unregistered informal firms in Egypt in 2008. However, data on sales are missing from that survey.

[6]We drop the top 0.4% (which corresponds to 64 firms) of the minimum wage to sales per worker in order to limit the influence of extreme values.

We use sales per worker as our primary measure of productivity.[7] The informal (formal) surveys provide firm-level total sales and the number of paid and unpaid workers for the last completed month (fiscal year) preceding the survey.[8] We compare this productivity measure to the minimum wage prevailing in the country during the survey-year (source: ILO). We define a firm to be not viable to minimum wage enforcement if the ratio of minimum wage to productivity is greater than unity.

To remain viable, the firm would need a productivity level that is well above the minimum wage otherwise the firm will not be able to remunerate the capital, to pay for intermediate goods, and in case of formal firms to pay social security contributions or other taxes and regulation costs. Thus, our measure of productivity is overstated. Given this, we consider $\mathcal{M} = 2$ as the markup of productivity P over the minimum wage which is needed to make the firm viable to minimum wage enforcement. That is, firms are solvent at the minimum wage if the minimum wage $\overline{w}$ is lower than 50% of productivity (i.e. $P > \mathcal{M} \times \overline{w}$).[9]

Measurement error in the sales and employment data we have used may lead to bias in our productivity measure. La Porta and Schleifer (2008) investigate the possibility that unregistered firms understate output more than registered small firms. They give evidence that supports the view that sales underreporting in unregistered firms does not result in biased productivity measures since unregistered firms also underreport inputs. Moreover, since the data do not provide the extent of informal employment in formal firms, which is very common in developing countries, measurement errors pose a problem in the formal sector as well. Interestingly, the incentive for underreporting output is to minimise tax liability. Thus, it is more likely to concern formal firms than informal firms who are not registered and not submitting returns to public authorities. Sales underreporting understates productivity. In order to handle possible measurement error bias, we assume an error level of 30% which translates into firms being viable if $P \times (1 + \mathcal{E}) > \overline{w}$ (where $\mathcal{E} = 0.3$).[10] Given this level of bias, the criterion for a firm to be viable is now $P \times (1 + \mathcal{E}) > \mathcal{M} \times \overline{w}$. In this regard,

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[7]We alternatively use the value added per worker which is defined as sales net of expenditures on energy, transportation and raw materials. Many firms did not report values for these additional variables but the results were very similar. Results are available upon request.

[8]The use of monthly data for informal firms allows to avoid potential measurement error for yearly data on sales and employment levels due to recall errors.

[9]See, for instance, Van Treeck (2020).

[10]The literature provides several methods for handling measurement error bias (Ashenfelter and Smith, 1979; Zhou and Oostendorp, 2014). For instance, sales underreporting is estimated to be 38.6% in Mongolia (Zhou and Oostendorp, 2014) and 30% in Sri Lanka (de Mel et al., 2009). In Latin America, sales underreporting accounts from less than 5% in Chile to 40% in Panama.

non-viable firms are those firms where the minimum wage is greater than 65% of productivity.

In what follows, we refer to non-viable firms as "Low productivity" firms using two indicative thresholds: an upper threshold of 1 and a lower threshold of 0.65 according to which a firm is low productive if the ratio of minimum wage to productivity is larger than 1 and 0.65, respectively.

Interestingly, sales underreporting and employment underreporting are positively correlated (World Bank, 2008; Perry et al., 2007). Thus, a downward bias due to sales underreporting and an upward bias due to employment underreporting might simultaneously affect our measure of productivity. Their effects on the ratio of the minimum wage to productivity could overlap if a firm underreports both sales and employment and are partially compensated. The overall measurement error bias could then be reduced and the lower threshold goes down further.

2.2. Low productivity firms: a comparison across the formal and informal sectors

Table 1 shows basic summary statistics for the total sample of firms and separately for formal and informal firms and by firm size. All in all, the ratio of minimum wage to productivity is on average 0.71. In particular, this ratio is equal to 1.34 and 0.33 among informal and formal firms, respectively. With respect to the upper threshold, low productivity firms represent 17.5% of the sample. A third of informal firms have low productivity, whereas low productivity firms represent 7.3% of formal firms. A fourth of all firms are low productivity when we use the lower threshold of 0.65 and, more precisely, almost half of informal firms and 11% of formal firms have low productivity. Statistics by firm size give evidence of a much lower productivity in small firms compared to larger firms.[11]

In Figure 1, we plot the cumulative distribution function of the minimum wage to productivity, separately for formal and informal firms. We indicate 1 and 0.65 as the upper and lower thresholds of the ratio of minimum wage to productivity. As shown in Figure 1, the distributions of the level of minimum wage to productivity are unequal between formal and informal firms. In particular, formal firms are more productive than informal firms for each level of the ratio. Moreover, the cumulative distributions for both the formal and informal firms have a diminishing slope so that lowering the threshold from 1 to 0.65 leads to a substantial increase in the number of non-viable firms (especially in the informal sector) and that the bulk of firms with a ratio higher than the threshold of 1 have very low productivity.

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[11]Among informal firms, 44.4% have one worker and 91% have 5 workers at most. However, 65% of formal firms have 11 workers and more.

Figure 2 examines the cumulative distribution function of the minimum wage to average productivity by country, separately for formal and informal firms. There is evidence of heterogeneity in productivity performances among countries.[12] In some developing countries, a substantial share of informal firms have productivity levels that would prohibit them from operating profitably at the minimum wage. For instance, in Argentina, 75% of informal firms have average sales per worker lower than the monthly minimum wage. This share is 62% in Zambia, 55% in Guatemala, 53% in Mozambique and Kenya, 36% in Cambodia and 35% in Ivory Coast. Using the second threshold for non-viable firms, Figure 2 shows that the 0.65 threshold line on the CDF is on a very steep part of the curve for many countries.

2.3. Workers in low productivity firms

Since the surveys provide employment by firm, we compute the fraction of workers in low productivity informal and formal firms. All in all, low productivity firms employ a large share of workers in the informal sector. However, low productivity firms account for a small share of employment in the formal sector. We consider again the two cut-off levels of 1 and 0.65 for the minimum wage relative to productivity. Statistics from our sample indicate that 34.2% to 48.4% of workers in the informal sector are employed by low productivity firms. In the formal sector, workers in low productivity firms account for 7.3% to 11% of total workers.

Besides statistics over the pool of countries, we find evidence of disparities across countries and across the formal-informal sector. Results are shown in Figure 3. For instance, among the 454 persons who work in informal firms in Argentina, 79% to 90.5% are in low productivity firms which are not viable to minimum wage enforcement. Importantly, the fractions of firms and workers in Figures 2 and 3 show comparable results. For instance, in Zimbabwe, depending on the cut-off level we consider (1 or 0.65), 29.1% to almost 46.6% of informal firms are low productive and not viable to minimum wage enforcement, and they employ 29.6% to 45.3% of workers in the informal sector.

2.4. Average productivity and average wage in informal firms

For 17 countries, the surveys provide the average monthly wage for workers in each informal firm.[13] We focus on informal firms since the formal enterprise surveys do not provide the average wage per worker. After controlling for missing values, we are left with a total sample of 3,188

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[12]This is partly due to the diversity in minimum wage legislation, some countries fixing a high level and the others a low level of the minimum wage.

[13]The surveys from Lao, Mozambique, Niger, Zambia and Zimbabwe do not provide the average wage per worker.

informal firms.[14] Basic statistics show a disproportionate number of low productivity informal firms that are likely to be paying an average monthly wage per worker less than minimum wage. In particular, 86% and 83% of informal low productivity firms (defined at the thresholds of 1 and 0.65, respectively) pay a monthly wage less than the minimum wage. At the same time, 37% of all informal firms who pay an average monthly wage per worker less than the minimum wage are low productive.

Furthermore, we plot in Figure 4 the average of labour productivity computed at the country level against the average wage in informal firms. The scatterplot shows a positive relationship. In countries like Argentina with a big fraction of low productivity informal firms, the average wage is low with respect to legal minimum wage. Similarly, in countries like Botswana and Angola, with a small fraction of low-productivity firms, average wages are high with respect to legal minimum wage. In Figure 5, we present the box plot of the ratio of minimum wage to average wage in informal firms by country and separately for low productivity (minimum wage to productivity higher than 1) and medium/high productivity (minimum wage to productivity lower than or equal to 1) firms. We see that average wages are smaller and have a higher volatility with respect to legal minimum wage in low productivity firms than in medium/high productivity firms.

2.5. The determinants of low productivity

As basic statistics have shown previously, there are differences in productivity by countries and by firm's formal/informal status. Of course a lot of this may be driven by differences across firms. In Table 2 (column 2) we show the results of the probit estimation that indicates which characteristics predict low productivity status. Our main explanatory variable is the indicator of the informal sector.[15] We include a dummy for manufacturing, the age of the firm (in years), the firm size defined as (log of) the total number of employees at the firm during the last completed month preceding the survey, the capital intensity per unit of labour[16], and four dummies for the firm's locality size (in number of inhabitants). Given that the firms' size may have different impacts on labour productivity in the informal firms compared to formal firms, we further include the interaction term between the informal firm dummy and the firm size (Amin and Islam, 2015).

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[14]We drop the top 0.7% (which corresponds to 22 firms) of the minimum to average wage per worker in order to limit the influence of extreme values.

[15]Of course, estimated parameters do not reflect causal effects as estimations do not deal with endogeneity issues.

[16]We consider (the log of) the value (net of depreciation) of the firm's assets like vehicles, machinery and tools. To deal with the various currencies from the range of countries we study, we apply the exchange rate of each local currency to the US dollar from the same year of the survey.

Country and year fixed effects capture all determinants of low labour productivity that are common to all firms within a country and a year. After controlling for missing values on variables of interest, we get a sample of 11,019 firms from both the formal and the informal sectors.

Importantly, the results in columns (1) to (3) in Table 2 show that low productivity firms are more likely to operate in the informal sector. On average, the probability of having low productivity is 11 percentage points higher for informal firms. We find that low productivity firms are likely to employ less workers, but not in the informal sector. The interaction term between the informal firm dummy and the firm size is large, positive and statistically significant at the 1% level. Among informal firms, the odds of being low productivity increases with firm size. The probability of having low productivity is larger for firms which have a manufacturing activity and operate in large cities with a population over one million persons. Finally, the odds of having low productivity decreases with the firm's age and the level of capital intensity per unit of labour.

We now use the pool of countries from the IFS and run a probit estimation to analyse the determinants of low productivity in informal firms. What are the common characteristics of low productivity informal firms? And can the authorities easily recognise and ignore them in their inspection efforts? We drop observations with missing values on the variables of interest and we remain with a sample of 2,412 informal firms. The results in columns (4) to (6) in Table 2 show that increases in the size of informal firms have a substantial positive impact on the probability of having low productivity. Firms with high capital intensity per unit of labour are less likely to have low productivity. The results suggest that there is no significant difference for informal firms from being older or from operating in the manufacturing sector. However, firms located within household premises have low productivity. If we look at the effects of owner's characteristics, we find that (i) firms owned by women are more likely to have low productivity, (ii) the odds of having low productivity decreases with the owner's age but at a decreasing rate, and (iii) a post-secondary education level for owner decreases firm's likelihood of being low productive.

3. Enforcement in developing countries: a survey

The enforcement of minimum wages is the responsibility of labour inspectorates in most countries. Labour inspection systems vary considerably from country to country as does their capacity to enforce labour legislation based on factors such as the number of inspectors, the number of inspections undertaken, the training quality of inspectors, and the number and amount of penalties imposed in practice. Sanctions are not effective unless they are enforced. In fact, one reason for the

low compliance with minimum wages is that public enforcement regimes are weak (Bhorat et al., 2012; Piore and Schrank, 2008; Ronconi, 2010). Thus, besides the importance of the legal structure of a sanctions system, compliance depends on the effectiveness of administrative processes and judicial proceedings for enforcing sanctions. Higher inspections do not necessarily translate into greater enforcement. For instance, in Bangladesh, whereas 411,518 and 610 violations are detected in 1988, 1989 and 1990, respectively, only 16 prosecutions are reported over the period 1990-1991 (Squire and Suthiwart-Narueput, 1997). The United Arab Emirates (UAE) report a total of 8,550 and 17,107 violations in 2008 and 2009, respectively, as a result of inspection visits (Vega Ruiz and Robert, 2013). However, only 245 and 355 employers were prosecuted in 2008 and 2009, respectively.

Financial sanctions are the most common category of sanctions for violations of minimum wage provisions. In some countries, employers who fail to comply are liable to a fine, imprisonment or both. This is the case in Botswana, India, Indonesia, Lebanon, Mexico, Philippines, Zambia and Zimbabwe. Note also that some countries draw a distinction between an employer as an individual and as a corporate entity. This is the case, for example, in Cuba. Other penalties can be imposed, that is firms may be closed down (Bolivia) or closed temporarily (for a period of up to four months in Nicaragua). In countries like Algeria, Argentina, Benin, Cameroon, Iran, Morocco and Tunisia, a fine is applied for each violation. The amount of the fine in each country is a function of the size of the firm, the number of workers concerned with non-compliance, and the seriousness of the violation.[17] Penalties may also increase in the case of repeat offences. In some countries, as shown in Appendix A, the amount of penalties is linked to the minimum wage. In Guatemala, for example, inspectors are empowered to impose penalties ranging from two to fourteen times the minimum wage, depending on the gravity of the offence. Similarly, in Bolivia, Cambodia, Honduras, Iraq, Kazakhstan, Montenegro, Mozambique and Venezuela the fine is a multiple of the reference minimum wage.[18] The amount of the fine is clearly an important concern. On the one hand, a small fine is likely to be ignored and has little or no effect on compliance and, on the other hand, an onerous fine, if strictly enforced, could make a firm vulnerable and threaten the jobs of its workers. Gindling and Terrell (2009) argue that in Honduras it is unlikely that very small employers are able to pay fines. Accordingly, and given scarce resources, labour inspectors focus enforcement efforts almost entirely on larger firms. The same applies in Yemen where the high-risk sectors, mainly small and medium enterprises, are never visited by the labour inspectors (ILO, 2009). We will present

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[17]In Arab countries, the level of fines depends usually on the nature of the violation (Vega Ruiz and Robert, 2013).

[18]Other countries, like Honduras, set fine amounts that have no correlation to the minimum wage.

evidence later which suggests that in some countries at least, compliance with the minimum wage would make many informal firms unviable.

There are reasons to assume that enforcement of minimum wage legislation is not randomly assigned.[19] Labour inspectors generally intervene both reactively (i.e., when complaints are received) and proactively (i.e., when inspections are based on strategic planning). In many developing countries, as shown in Appendix A, inspections are the combination of the two strategies. However, according to the ILO, when it comes to minimum wage provisions, inspections are mostly triggered by complaints. This is the case in India, Bahrain, Palestinian Territory, Syria, Thailand, Lebanon and Uganda (ILO, 2006, 2014a). In Lebanon, the enormous number of complaints registered in the Ministry of Labour exceeds its economic capacity and the human resources needed to handle them. Similarly, in Honduras, the central work of labour inspectors is oriented to carrying out special inspections in response to individual or collective claims. In Ecuador and Morocco, for example, unions reportedly act as important channels and play an important role in the transmission of complaints regarding violations of labour regulations (Squire and Suthiwart-Narueput, 1997). In Turkey, 26,645 workplaces were investigated in 2005 as a consequence of denunciations and complaints (ILO, 2009), and there is a greater emphasis on responding on a case-by-case basis to complaints in Vietnam. In Guatemala, 4,601 visits were made on the basis of allegations in 2003 and 2,098 in 2004 and each allegation led to at least two inspection visits. A more comprehensive system has been developed in Jordan, Kuwait, UAE and Saudi Arabia. For instance, a toll-free hotline service (serving in multiple languages) is available in Jordan since 2006 to provide advice to workers on legal matters and information needed to enable them to submit complaints and report labour law violations. The hotline registered 892 complaints in 2013. The UAE established a fully computerized hotline service, which receives complaints from national and migrant workers in 13 languages. The service received 527,521 calls in 2009. A specific system is implemented in Costa Rica in 2010 – the National Campaign for Minimum Wages – in order to increase compliance with minimum wage legislation (ILO, 2016; Gindling et al., 2015). The Campaign encouraged workers who receive sub-minimum wages to denounce, anonymously via a telephone hotline, their employers and increased labour inspections targeting minimum wage violations (Vega Ruiz, 2009). This hotline received tens of thousands of calls. In many countries the minimum wage or its periodic readjustment does not apply to agriculture. For example, in Panama and Qatar there is no labour

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[19]For example, Ashenfelter and Smith (1979) conclude that the US government's strategy for enforcement is far from random.

inspection in agriculture enterprises. Wages in agriculture tend to be low and many rural workers are paid below the legal minimum wage. Argentina made agriculture part of the inspection visits programme. During 2010 and 2011, labour inspectors organized intensive inspection blitzes during the fruit harvest and found, for instance, that 15 over 19 visited enterprises in Mendoza region had compliance problems[20].

In summary this review suggests that while the level of penalties and enforcement of penalties varies widely, there is direct evidence for some countries that inspections are targeted at larger firms and widespread evidence from many countries that worker complaints are the primary driver of inspections. In the following section, we model non-compliance with minimum wage in developing countries by considering the facts that workers' complaints are crucial and in equilibrium, workers in low productivity firms will not complain. Besides, the amount of the penalty is function of the size of the non-compliant firm, the number of underpaid workers and the gravity of the violation.

4. A monopsony model with non-compliance and worker complaints

4.1. The model without a minimum wage

As a starting point for our theoretical analysis, we outline a standard monopsony model with no minimum wage.[21] The workers and firms are long lived. We will outline a stationary equilibrium where the decision facing the worker/firm will be identical in each period and so we suppress notation for time. In each period of time the firm must pay a fixed rental capital cost of k. A firm could shut down and rent some more capital to reopen in the subsequent period. For convenience, we assume no shutting cost so that the workers optimisation problem will in any period of time be time-independent.

This simplified partial equilibrium framework enables us to reproduce the observed empirical regularities. The labour market is represented by multiple firms, each located at the end of a unit interval. There is a mass ψ of workers uniformly distributed along the interval, where each worker has a reservation utility $\bar{u}$. The production function is: $y = F(l)$ where l is the number of employed workers. We assume that $F_l(l) > 0$ and $F_{ll}(l) < 0$. The transport costs associated with travelling a distance x to go to work is tx for all individuals. We can think of the transport costs as representing

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any firm specific preferences employees may have based on location, work practices in the particular firm, knowing others that work there and so on. Bhaskar and Ted (1999) outline a model of this type in some detail. An individual who is within distance x^0 of the firm will be willing to work as long as the wage net of transport costs is at least as great as the outside option: $w - tx^0 \geq \bar{u}$.

Thus the share of individuals who are willing to work is given by:

$$x^0 = \frac{w - \bar{u}}{t} \tag{1}$$

As a result the labour supply curve and the inverse labour supply curve facing every firm are:

$$l = x^0 \psi = \frac{\psi(w - \bar{u})}{t} \qquad w = \frac{t}{\psi}l + \bar{u} \tag{2}$$

The total and marginal costs of labour are:

$$TC = wl = \frac{\psi(w - \bar{u})w}{t} \qquad MC = \frac{\partial TC}{\partial w} = \frac{\psi(2w - \bar{u})}{t} \tag{3}$$

We assume that firms cannot discriminate across workers. That is all workers at a firm must be paid the same wage. We also note that we have simplified the model by assuming that firms are distributed on circle such that the distance between each firm is equal but large enough so that firms do not compete for workers. For example, say the circle is big enough and consider a firm i and a worker j. Firm i is the closest to worker j, who has a marginal productivity at firm i that is equal to transport costs times the distance to firm i. We consider there is no other firm k on the circle where transport costs times the distance of worker j from firm k would be less than worker j's marginal productivity at firm k. This assumption avoids a situation where a firm's labour supply curve depends on wages in other firms, as in Bhaskar and Ted (1999) for example. As we will outline in more detail below, all firms face the same labour supply curve but firms may differ in their productivity so that there will be large and small firms where more productive firms will be larger in equilibrium. When we introduce a minimum wage, firms with productivity above a certain threshold will be unaffected by the minimum wage since their profit maximising wage will be above the minimum in any case.[22]

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[22] We will of course need to be sure that a firm that would pay over the minimum wage in the case of full compliance cannot deviate to paying less than the minimum wage and make a higher profit. For example, in BCK, the presence of the minimum wage and the possibility of a firm being caught and forced to repay workers underpayments in wages can increase a non-compliant firm's labour supply relative to what labour supply would be in the absence of a minimum

4.2. A minimum wage with imperfect enforcement

In our model, firms operate either in the formal or the informal sector, however the only government regulation we include explicitly in the model is non-compliance with the minimum wage. The timing in any period is as follows.

1. The government commits to a minimum wage $\overline{w}$.

2. Firms choose a wage w and the number of workers.

3. Workers in non-compliant firms decide whether to submit complaints to the labour inspectorate.

4. Inspections for non-compliance with the minimum wage are carried out with a probability $(\lambda + \delta c)$ where λ is a constant exogenous probability of an inspection, δ is the rate at which complaints are inspected, and c is the number of workers who will decide to make complaints in any firm. The value of the policy parameters λ and δ are common knowledge.

5. The firm may respond to the inspection by shutting down in which case their workers will get nothing, or else they may continue in business. If they stay in business firms who were caught in non-compliance must pay all their workers the minimum wage and pay a penalty of $[\rho(\overline{w} - w)l]$ to the government, where $\rho \geq 0$ and l is employment in the non-compliant firm.[23] The parameter ρ will have an important role in determining the productivity threshold at which a firm will choose to be non-compliant.

We assume that $w > \overline{u}$. That is, we assume that workers are credit constrained so that the wage cannot fall below the subsistence level which is the outside option. As in BCK, there is a transaction cost associated with receiving a refund of underpaid wages as a result of an inspection so that the utility employed workers receive from a refund is:

$$\sigma \left[(\overline{w} - w)l(\psi, w) \right] \quad \text{where} \quad \sigma \leq 1 \tag{4}$$

BCK assume that $\sigma < 1$, i.e. the benefit to the worker from the repayment of lost wages is less than the money value. We rather assume $\sigma \leq 1$ to show that our results are not sensitive to this parameter value being less than unity.[24] Note that we would expect that informal firms

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wage. We will see below that high productivity firms will never deviate to non-compliance in the equilibrium we outline since they would certainly be caught.

[23]If $\rho > 0$ this will penalise non-compliant firms by more than the underpayment of wages.

[24]We will allow firms who are caught in non-compliance to increase their employment after being caught if they wish. If we restricted firms to not increasing employment it would change the details of some of the proofs, but not the results.

would often encounter a larger penalty than implied by the model whenever a complaint filed by a worker is inspected. That is an inspection of informal firms may well result in the firm undergoing a penalty for non-compliance with tax or other regulations besides the penalty for non-compliance with minimum wage regulations.

We assume that unfair dismissal legislation prevents a firm that has been caught in non-compliance from discriminating against workers they suspect have made a complaint. In fact, there may be many situations where workers are fearful of complaining due to the possibility of dismissal. It is important to consider though that a firm with high productivity, where workers are confident that, even if caught, the firm will wish to maintain the same employment level may find it difficult to credibly commit to punishing complainers. In a model with frictions where all workers have the incentive to complain, this will be particularly true. If firms face an upward sloping labour supply curve as in our model, they may need to increase the offered wage if they dismiss current workers and seek to replace them with workers further up the labour supply curve. We note again that our results hold for any value of $\sigma \leq 1$. That is, even if the worker substantially discounts the expected benefit of complaining, the results will hold if there is any gain to complain. This certainly supports an intuitive argument that, as long as the possibility of being identified and punished is not too high so that workers still expect to gain, workers would still have the incentive to complain, especially where replacing workers is costly. A more realistic model would also account for the fact that workers who believe their productivity is low relative to the minimum wage may worry more about dismissal if they complain[25]. Indeed, while some firms may adopt a strategy of hiring vulnerable workers who are afraid to complain, this is less likely to be a viable strategy for the main body of firms. Given these arguments we do believe that it is plausible to argue that there are many cases where many high productivity firms would find it difficult to credibly commit to punishing complainers. Of course, for low productivity firms, this is not an issue since workers do not have the incentive to complain.

4.3. Enforcement increasing with employment

Anticipating the equilibrium which will emerge from the model we note that the value of the probability of an inspection will be either $(\lambda + \delta l)$ or λ. We will justify this assumption below when we see that depending on the productivity of the firm, either all workers or no workers at a firm will

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[25]In their analysis of non-compliance in the US, Clemens and Strain (2020) develop an illustrative framework to account for the fact that complaints are worker driven in the US. This demonstrates that workers with lower ability may have a lower incentive to complain fearing dismissal if the minimum wage were enforced.

have the incentive to complain. It is clear from our survey of enforcement regimes in Appendix A that in many jurisdictions the primary instigator of inspections is complaints by workers, but often there is also a random probability of an inspection. The formulation we adopt here captures these features of the inspection regime. We will outline below how this implies that in equilibrium the probability of an inspection is one of the two values given above.

It will become clear that it is important to distinguish between three categories of firms: *High*, *Low* and *Medium* productivity firms. As we will see below, the value for a productivity parameter P will vary across firms and will be multiplied by a function increasing in the number of workers but with diminishing marginal returns, which is common to all firms, to determine output. A *High* productivity firm has a value for the productivity parameter such that the profit maximising wage is at or above the minimum wage and so the firm's choice of wage and employment in any period will be unaffected by the minimum wage. A *Medium* productivity firm has lower productivity in a range where the minimum wage is binding, but where productivity is high enough such that if the firm were to choose to not comply with the minimum wage, it would be viable if it was caught in non-compliance. This means that if a *Medium* productivity firm was caught in non-compliance it would prefer paying the penalties due and continuing to trade at the minimum wage to shutting down. A *Low* productivity firm is a firm with a value for the productivity parameter such that if it was caught in non-compliance, it would shut down rather than paying the penalties due and continuing to trade.

A key point to note here is that workers in *Medium* firms would always have the incentive to complain if their employer were to not comply with the minimum wage since this increases the possibility of inspection which would increase the workers wage. Workers in *Low* firms would never complain since this only increases the probability of an inspection which would result in firm closure and job loss. The threshold level of productivity which determines whether a firm is a *Low* or *Medium* firm is endogenous.

In reality, workers may have an imperfect signal of productivity. Appendix C has some analysis of this case. We show that even if workers receive a noisy signal of productivity, there will very likely be a range of productivities where the signal of productivity observed by workers is high or low enough that the worker can be fairly certain of the firm's type. Indeed, our empirical analysis shows that when we look at the distribution of productivity, a substantial share of informal firms are well below the threshold that would make them viable at the minimum wage, even if we account for the possibility of a reasonable degree of measurement error. If this range where the firm's type

is ambiguous is not too large, there will be many firms where the incentives outlined in the paper will continue to hold. Workers in unproductive firms will have the incentive not to complain while workers in firms that have reasonably high productivity would have a much greater incentive to complain and this would deter non-compliance.

The case of Medium non-compliant firms.. In this section we focus on *Medium* firms. In the case where $\sigma \leq 1$ and where all workers will complain in such a firm if it is non-compliant, the probability of an inspection equals $(\lambda + \delta l)$. The expected utility of a worker in such a firm if the firm is non-compliant (i.e. paying a wage $w < \overline{w}$), is[26]:

$$EU = [1 - (\lambda + \delta l)]w + (\lambda + \delta l)[w + \sigma(\overline{w} - w)] - tx = w + (\lambda + \delta l)\sigma(\overline{w} - w) - tx > \overline{u} \qquad (5)$$

where $0 \leq \lambda < 1$, $0 < \delta$, $0 \leq (\lambda + \delta l) \leq 1$, and $l > 0$.

The restriction that $(\lambda + \delta l) \leq 1$ just implies that the probability of a firm being caught in noncompliance should be no higher than unity even if all workers complained. In effect this means that for a given level of employment l there is an upper bound for $\delta = \delta_{Max}$ such that the firm is certain to be caught in non-compliance given their wage. We will solve for this upper bound below. We note that while the authorities could choose a value for $\delta > \delta_{Max}$ which was greater than the upper bound, we should include the upper bound in the expected utility function if they chose to do so. If the worker is certain that the firm will be caught in non-compliance, increasing this parameter above the upper bound value cannot have any additional effect on the worker's utility and so will not affect the labour supply curve we derive below.

The probability that the firm will be caught and the worker compensated is $(\lambda + \delta l)$, in which case the worker receives $[w + \sigma(\overline{w} - w)]$. The probability the firm will not be caught is $[1 - (\lambda + \delta l)]$ in which case the worker receives w. Of course, either way the worker will lose transport costs of tx when they go to work. We note that the above equation is written from the point of view of a worker who is offered a wage by a given firm. Each worker takes the number of workers that the firm will optimally choose l as given when s/he calculates the probability the firm will be caught for non-compliance: $(\lambda + \delta l)$. This probability is multiplied by the wage plus the utility value to the worker of the back wages s/he receives from the employer. We are assuming that all workers in the firm complain in the equation since as noted earlier they can only gain by doing so. We also note

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[26]In the case where $\sigma = 1$, the expected wage must exceed the outside option plus transport costs, that is $w[1 - (\lambda + \delta l)] + (\lambda + \delta l)\overline{w} > \overline{u} + tx$.

that at the beginning of the subsequent period a worker in this firm will face the same expected utility function as outlined above since, even if a firm is caught in non-compliance, it can revert to non-compliance in subsequent periods and will do so if the per period expected profit is higher. It may seem implausible that a firm could be caught, forced to pay its workers the minimum wage and then be able to cut wages again in the subsequent period. It is important to remember that this is an out of equilibrium possibility. In fact, we will see that in equilibrium any firm which can afford to pay the minimum wage will not choose to do this because it will be immediately caught.

We note that the expected utility of being in a non-compliant firm is higher the higher is the level of employment (for given values of the other parameters) and for any given wage, since this increases the probability the firm will be caught and the worker compensated if the probability of worker complaints is positive. From the expected utility term above, the distance from the firm at which a worker in a sub-minimum wage firm would be indifferent between working and not working would be:

$$\tilde{x} = \frac{w + (\lambda + \delta l)\sigma(\overline{w} - w) - \overline{u}}{t} \tag{6}$$

Following from this, the labour supply curve in such a firm can be solved as follows, $\overline{u}$ is the utility available in self-employment. From the expression for the distance to the marginal worker given above, we note that labour supply will satisfy the following equation:

$$lt = \tilde{x}\psi t = \psi \left[w + (\lambda + \delta l)\sigma(\overline{w} - w) - \overline{u} \right] \tag{7}$$

The number of workers is on both sides of this equation and can be solved as follows so that we get the labour supply curve for a non-compliant *Medium* firm:

$$l = \frac{\psi \left[w - \overline{u} + \lambda\sigma(\overline{w} - w) \right]}{t - \psi\delta\sigma(\overline{w} - w)} \quad \text{where} \quad w < \overline{w} \tag{8}$$

We note that since $w > \overline{u}$ the numerator of the labour supply curve is positive, implying that the denominator is positive also since labour supply is positive: $t > \psi\delta\sigma(\overline{w} - w)$. We note that the constraint that the probability of detection is less than unity puts the following restriction on the

wage of a non-compliant firm[27]:

$$\lambda + \delta l = \frac{\lambda \left[t - \delta \psi \sigma(\overline{w} - w) \right] + \delta \psi \left[w - \overline{u} + \lambda \sigma(\overline{w} - w) \right]}{t - \psi \delta \sigma(\overline{w} - w)} < 1 \tag{9}$$

This can be simplified to:

$$\delta \leq \frac{t(1 - \lambda)}{\psi \left[w(1 - \sigma) + \sigma \overline{w} - \overline{u} \right]} = \delta_{Max} \tag{10}$$

The implication is that if this inequality was violated, a firm paying the given wage would be certain to be caught in non-compliance. As noted earlier this is effectively an upper bound for δ. Also noted above, the numerator of the labour supply function is positive: $\left[w - \overline{u} + \lambda \sigma(\overline{w} - w) \right] > 0$. This is important at this stage since it implies that the derivative of the labour supply function with respect to the punishment parameter δ is positive: $\frac{\partial l}{\partial \delta} = \frac{\psi^2 \sigma(\overline{w} - w)[w - \overline{u} + \lambda \sigma(\overline{w} - w)]}{[t - \psi \delta \sigma(\overline{w} - w)]^2} > 0$. This means that we can impose the maximum value for $\delta = \delta_{Max}$ [from inequality (10] for given values of the wage and λ, such that a non-compliant firm paying that wage is certain to be caught. If we introduce δ_{Max} into equation (8), we obtain for the *Medium* firm the maximum labour supply possible at a given wage or the labour supply at that wage where the worker knows the firm is certain to be caught in non-compliance:

$$l_{max}^M(w) = \frac{\psi \left[w(1 - \sigma) + \sigma \overline{w} - \overline{u} \right]}{t} \tag{11}$$

We note that since this is increasing in the wage the highest labour supply a non-compliant *Medium* firm could have is where the wage equals the minimum wage, that is the maximum labour supply available to a compliant firm $l_{max}^M(\overline{w}) = \frac{\psi(\overline{w} - \overline{u})}{t}$. We also note that the denominator of the labour supply curve cannot be negative: $t > \psi \delta \sigma(\overline{w} - w)$. From equation (8), the restriction that labour supply must be positive implies the following inequality:

$$\frac{\psi \left[w(1 - \lambda \sigma) + \lambda \sigma \overline{w} - \overline{u} \right]}{t - \psi \delta \sigma(\overline{w} - w)} > 0 \tag{12}$$

We see that since the denominator is positive and the numerator is increasing in the wage then the

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[27]If a *Medium* firm pays the minimum wage, the firm can choose to hire any number of workers up to $l = \frac{\psi(\overline{w} - \overline{u})}{t}$ at the minimum wage. A *Medium* firm would never wish to hire more workers than this at the minimum wage. Only a *High* firm would wish to do this. Indeed, by definition, a *High* firm is a firm that would choose a wage higher than the minimum wage.

lowest wage that will guarantee positive labour supply must exceed:

$$w_{Min} = \frac{\overline{u} - \lambda\sigma\overline{w}}{1 - \lambda\sigma} \tag{13}$$

Next we wish to show that the threshold value for δ at which a firm is certain to be caught in non-compliance for given values of the wage and λ is increasing in the wage. This will allow us to solve for a critical value of δ such that if we impose the lowest wage a firm could offer [which is given in inequality (13) above] in inequality (10) which gives the value of δ where a firm is certain to be caught for a given wage, then if the authorities set δ at this critical value it will ensure that any firm with positive labour supply is certain to be caught in non-compliance. The derivative of the right-hand side of inequality (10) is:

$$\frac{\partial \left[\frac{t(1-\lambda)}{\psi[w(1-\sigma)-\overline{u}+\sigma\overline{w}]} \right]}{\partial w} = -\frac{\psi(1-\sigma)t(1-\lambda)}{\{\psi[w(1-\sigma)-\overline{u}+\sigma\overline{w}]\}^2} < 0 \tag{14}$$

That is the threshold on the right-hand side of inequality (10) is decreasing in the wage. Next we substitute the minimum wage the firm can offer and have positive labour supply from inequality (13) into inequality (10) and solve for the level of δ. δ^* is the threshold level of the probability a complaint will be investigated above which the probability of detection would be certain for a non-compliant *Medium* firm paying any wage $w > w_{Min}$:

$$\delta^* = \frac{t(1-\lambda)}{\psi[w_{Min}(1-\sigma)-\overline{u}+\sigma\overline{w}]} = \frac{t(1-\lambda\sigma)}{\psi\sigma(\overline{w}-\overline{u})} \tag{15}$$

Proposition one. As long as $w > \overline{u}$,

(a) there is a threshold for the intensity of inspections per complaint $\delta^* = \frac{t(1-\lambda\sigma)}{\psi\sigma(\overline{w}-\overline{u})}$ at or above which a *Medium* firm would be certain to be caught in non-compliance given the level of worker complaints;

(b) it will be optimal for the firm to be compliant with the minimum wage if the intensity of inspections per complaint is greater than or equal to the threshold in part (a).

Proof:

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(a) Inequality (10) shows a level of δ at or above which a firm will be certain to be caught in non-compliance at the level of employment implied by a given wage if the firm is on the labour supply curve. The right hand side of inequality (10) is decreasing in the wage, so if we ensure that the inequality holds with equality for at least the lowest wage w_{Min} that guarantees zero or positive labour supply, then δ will be high enough to ensure a non-compliant *Medium* firm is caught at any higher wage it might choose.

(b) The profit function of any *Medium* firm if it is compliant is:

$$\pi(P^M) = P^M F[\bar{l}(P^M)] - \overline{w}\bar{l}(P^M) \tag{16}$$

The labour supply curve of the firm is: $\bar{l} \leq \frac{\psi(\overline{w}-\overline{u})}{t}$ where depending on the productivity level (P^M), the firm's value of marginal product of labour may equal that of the minimum wage at less than $\frac{\psi(\overline{w}-\overline{u})}{t}$ and the firm will not hire all the workers willing to work for it at the minimum wage (the firm is demand constrained), or the value of marginal product is greater than or equal to the minimum wage at $\frac{\psi(\overline{w}-\overline{u})}{t}$ so that the firm would hire all workers available to it at the minimum wage and is supply constrained. We will denote the profit maximising employment choice of the firm if it is compliant as $\bar{l}^*$. Given (a), if the firm had chosen to be non-compliant, it knows that it would be caught and penalised when it chooses $w < \overline{w}$. Given this employment would be chosen to maximise the profit function:

$$\pi(P^M) = P^M F(l^{NC}) - \overline{w}l^{NC} - \rho(\overline{w} - w)l^{NC} < 0 \tag{17}$$

Since workers know the firm is certain to be caught in non-compliance, the labour supply curve facing such a firm is given in equation (11): $l^M_{max}(w) = \frac{\psi[w(1-\sigma)+\sigma\overline{w}-\overline{u}]}{t}$. The optimal level of employment of the firm if it is non-compliant firm is denoted l^{NC}.

We note that once the firm has been caught in non-compliance it will have chosen l^{NC} before being caught. Relative to a profit maximising compliant firm we see immediately that the first part of inequality (17) above is the same as the compliant firms profit function, and that this term can be no greater than the profit the firm would make as a profit maximising compliant firm:

$$\left[P^M F(l^{NC}) - \overline{w}l^{NC}\right] - \left[P^M F(\bar{l}^*) - \overline{w}\bar{l}^*\right] \leq 0 \tag{18}$$

Next we note that since the second term in the non-compliant firm's profit function is negative: $-\rho(\overline{w} - w^*)l^{NC}$, then the firm will have higher profit in compliance compared to non-compliance if it is sure to be caught.

The above proof shows that there is a threshold for the intensity at which complaints are investigated, so that any *Medium* non-compliant firm on the labour supply curve is certain to be caught if it does not comply with the minimum wage. This means that non-compliance will certainly lower profit relative to compliance and any *Medium* firm will comply.

The case of Low non-compliant firms.. Next, we consider *Low* firms, which may be viable in non-compliance but could not be viable at the minimum wage if they were caught employing non-compliant workers. That is, workers in these firms know that if the firm is inspected it will close and the worker will not be compensated and so have no incentive to complain. The equilibrium number of complaints is zero for this reason, and the probability of inspection in equilibrium is λ. While compliance with the minimum wage is the only difference between formal and informal firms in the model, informal firms which are common in developing countries typically do not comply with many other regulations in addition to the minimum wage. We note that these informal (unregistered) firms typically have low productivity. If workers in an unregistered non-compliant firm complain and the firm is inspected then the penalty is likely to be higher compared to the penalty suffered by registered non-compliant firms everything else equal, since unregistered firms will be penalised for non-compliance with regulations other than the minimum wage. Arguably this makes workers in such firms even less likely to complain.

The condition that expected utility is greater than the outside option for a worker in a *Low* non-compliant firm is:

$$EU = (1 - \lambda)w - tx > \overline{u} \tag{19}$$

From the expected utility term above the distance from the firm at which a worker in a sub-minimum wage firm would be indifferent between working and not working would be:

$$\tilde{x} = \frac{(1 - \lambda)w - \overline{u}}{t} \tag{20}$$

Following from this the labour supply curve in such a firm can be solved as follows where we will assume that $\overline{u}$ is a subsistence wage available in self-employment and that credit constraints

prevents $w \leq \overline{u}$. From the expression for the distance to the marginal worker given above we note that labour supply and inverse labour supply will satisfy the following equations:

$$l = \frac{\psi \left[(1 - \lambda)w - \overline{u} \right]}{t} \qquad w = \frac{tl + \psi \overline{u}}{\psi(1 - \lambda)} \qquad (21)$$

The labour supply curve is the same as the labour supply curve with no minimum wage (Equation 2), except that the wage is adjusted for the probability the firm will be inspected randomly (at rate λ) and shut down since the firm will be unable to pay the penalty. The only expected benefit the worker has from working at the firm is the wage they will get while working. If the firm is inspected it will shut down and the worker gets nothing. We note that for *Low* firms, since $(1 - \lambda) < 1$ the labour supply curve has shifted inwards and the firm will attract fewer workers at any given wage compared to the pre minimum wage labour supply (Equation 2). This is in contrast to BCK, where the labour supply curve of non-compliant firms shifts outward relative to their pre minimum wage supply curve because workers account for the option value of the firm being caught and forced to pay the minimum wage. By contrast, workers in a *Low* firm are certain the firm will close if caught, random checks increase the probability that the firm will be shut down and lower the value of the job other things equal, reducing labour supply.

The expected profit of a *Low* firm is:

$$\pi(w, P^L, \lambda) = (1 - \lambda) \left\{ P^L F[l^L(w, \lambda)] - wl^L(w, \lambda) \right\} \geq k \qquad (22)$$

We label the productivity parameter P^L to denote that it is low enough so that if this firm were caught paying less than the minimum wage, it would become non-viable and close. We also note that if a minimum wage is introduced, there may be some firms who might profitably enter this market at a low wage if there were no minimum wage, but where they can no longer make sufficient profits to cover the fixed entry cost k if $\lambda > 0$.

Next, we analyse the profit of a *Low* firm if caught in non-compliance. A *Low* firm's profit must satisfy the inequality below to be insolvent if caught in non-compliance:

$$\pi(P^L) = P^L F[\overline{l}(P^L)] - \overline{w}\overline{l}(P^L) - \rho[\overline{w} - w(P^L)]l[w(P^L)] < 0 \quad \text{where } l[w(P^L)] \leq \overline{l} \leq l(\overline{w}) \qquad (23)$$

If the firm is caught and were to stay in business it must comply, so the first part of the profit function in inequality (23) is the profit function of a compliant firm: $PF(\overline{l}) - \overline{w}\overline{l}$ where employment

must be less than or equal to labour supply at the minimum wage: $\bar{l} \leq l(\overline{w})$.[28] The firms optimal choice of wage and labour supply before they were caught, which determines the penalties they are liable to pay after being caught are w and $l(w)$. If they were caught the firm would face a penalty of $\rho(\overline{w} - w)l(w)$.

We note that if it is profitable to hire additional workers after being caught $\bar{l} > l$, the firm will still be constrained by the labour supply available to it at the minimum wage $\bar{l} \leq l(\overline{w})$. We also note that after being caught the firm is precluded from firing any of its workers $l[w(P^L)] \leq \bar{l}$, but we will see that the firm will not wish to do this in the equilibrium we outline below. Since we assumed that k is the rental cost of the capital needed to produce and that firms could shut down and reopen in a new firm in the subsequent period, the firm faces the same optimisation problem in every period. To sustain non-compliance as an equilibrium strategy, we must show that if workers at the firm did complain, and the firm had to comply with the minimum wage and pay any penalties due as a result, then the firm would close rather than pay the penalty. That is the firm must be able to credibly commit to closing in the event of being caught in non-compliance.

Before being caught, an insolvent non-compliant firm would have maximised expected profit in accordance with equation (22) where there is a probability of $(1 - \lambda)$ that the firm would operate as a non-compliant firm and not be caught and a probability of λ that they would get zero (since they would close if they were caught). The first order condition from the profit function in equation (22) can be used to solve for the wage:

$$\pi_w(w, P^L, \lambda) = P^L F_l[l(w)]l_w(w) - wl_w(w) - l_w = 0 \tag{24}$$

We can solve this for the optimal wage w^* and the implied labour supply $l(w^*)$ and level of profit $\pi_w(w^*, P)$ of any *Low* firm. The second order condition is:

$$\pi_{ww} = P^L F_{ll}l_w l_w + PFl_{ww} - l_{ww}w - 2l_w = P^L F_{ll}l_w l_w + \frac{l}{l_w}l_{ww} - 2l_w \tag{25}$$

This is negative if $P^L F_{ll} \leq 0$ since we note from the labour supply curve above [equation (16)] that $l_w > 0$ and $l_{ww} = 0$.

Next we look at inequality (23) for the profit of a firm caught in non-compliance and take the

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derivative with respect to P^L. The reason for doing this is to demonstrate that a bad firm's profit in non-compliance is increasing in the productivity parameter as we would expect. This means there will be a threshold value for this parameter $\underline{P}$ above which the firm would not have the incentive to close if caught in non-compliance and workers would all have the incentive to complain. That is if $P > \underline{P}$ this means that this firm is a *Medium* firm.

$$\frac{\partial \pi}{\partial P} = F(\bar{l}) + \left\{ P F_l[\bar{l}(P)] - \overline{w} \right\} \bar{l}_P(P) + \rho w_P(P) \left\{ l[w(P)] - [\overline{w} - w(P)] l_w[w(P)] \right\} \tag{26}$$

We note that if the firm were to pay the minimum wage, which it must after being caught, then:

$$P F_l[\bar{l}(P)] - \overline{w} = 0 \tag{27}$$

Substituting equation (27) into equation (26) implies:

$$\begin{aligned} \frac{\partial \pi^t}{\partial P} &= F(\bar{l}) + \rho w_P(P) \left\{ l[w(P)] + w(P) l_w[w(P)] - \overline{w} l_w[w(P)] \right\} \\ &= F(\bar{l}) + \rho w_P(P) l_w[w(P)] \left\{ P F_l [l[w(P)]] - \overline{w} \right\} \end{aligned} \tag{28}$$

Proposition two.

(a) The profit of a firm which has been caught in non-compliance is increasing in the productivity parameter.[29]

(b) There is a threshold level of productivity $\underline{P}$ above which a firm cannot credibly commit to shutting down if caught in non-compliance. Firms with productivity at or below $\underline{P}$ will be *Low* firms where no worker has the incentive to complain in non-compliance, while workers in firms with productivity above the threshold know the firm would stay in business and pay them a higher wage if caught in non-compliance and will always complain.

(c) From Proposition one, if the probability a complaint will be investigated is at or above the level in equation (15) firms with productivity above the threshold level will be *Medium* firms and from proposition one will choose to be compliant in equilibrium or else shut down in response to the minimum wage.

Proof:

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[29]This is the profit function in inequality (23). The firm has already chosen the wage and number of workers and now must comply with the minimum wage and pay the penalty for all existing workers.

(a) We imagine a firm that has a given level of the productivity parameter P^x and has chosen the wage optimally and makes a given level of profit $\pi(w, P^x)$. After being caught in non-compliance the firm may adjust its employment to $l\left[w(P^L)\right] \leq \bar{l} \leq l(\overline{w})$. If this firm had a slight increase in productivity but did not adjust its wage or labour supply in response to this productivity change, the change in profits would be $F(\bar{l})$. If the firm did optimally adjust its wage this is captured in the remaining term in equation (26): $\left\{ PF_l[\bar{l}(P)] - \overline{w} \right\} l_P(P) + \rho w_P(P) \left\{ l[w(P)] - [\overline{w} - w(P)] l_w[w(P)] \right\}$. This is the increase in profit that the firm expects to receive by optimally adjusting the wage and labour supply in response to the increase in productivity. By definition this is non-negative, since the firm has the option of leaving the wage and labour supply unchanged in which case this term would equal zero.

(b) Since the level of profit an optimising firm would enjoy after being caught in non-compliance is increasing in productivity from inequality (26), once it reaches a level where profit as defined in equation (23) is positive, the worker knows the firm will stay open and pay the minimum wage if caught in non-compliance and so all workers complain. If the firm's productivity parameter is less than the threshold then the firm can credibly commit to closing if caught and no worker will complain.

(c) If the productivity parameter is above the threshold where all workers complain defined in (b) so that all workers complain when the firm is non-compliant, the firm's labour supply curve will be given by equation (8) for a *Medium* firm and by equation (21) for a *Low* firm. The difference between these labour supply curves is that equation (8) assumes all workers complain and equation (21) that no worker complains. Proposition one shows that when the threshold probability of an investigation is above that given in inequality (15), a firm with labour supply given by (8) will be more profitable in compliance than non-compliance. If compliance is not profitable it will shut down.

Proposition three. The threshold level of productivity at which a firm moves from being *Low* to *Medium* is increasing in the punishment parameter ρ.

   Proof:

To see this we show that for a given value of the productivity parameter P^L and the other parameters of the model, the profitability of a *Low* firm after being caught in non-compliance is

decreasing in ρ.

$$\pi(P^L) = P^L F[\bar{l}(P^L)] - \overline{w}\bar{l}(P^L) - \rho[\overline{w} - w(P^L, \rho)]l[w(P^L, \rho)] < 0 \quad \text{where} \quad \bar{l} \leq l(\overline{w}) \qquad (29)$$

The conditions for an increase in ρ to lower profits for a *Low* firm with given productivity are outlined below:

$$\frac{\partial \pi(P^L)}{\partial \rho} = -\left[\overline{w} - w(P^L, \rho)\right] l[w(P^L, \rho)] + \rho\frac{\partial w}{\partial \rho}l - \frac{\partial l^L}{\partial \rho}\rho\left[\overline{w} - w(P^L, \rho)\right] \qquad (30)$$

The first order condition for a *Low* firm is given in equation (24) and the labour supply curve is given in equation (21). We see from these equations that since a *Low* firm will shut down if caught, no worker will complain and the firm's optimal choice of wage and employment is independent of the punishment parameter ρ since the firm will close if caught and make zero profit whatever the value of this parameter is. In terms of the derivative in equation (30) this mean that $\frac{\partial w}{\partial \rho} = \frac{\partial l}{\partial \rho} = 0$. It follows that equation (30) can be rewritten as follows and is negative:

$$\frac{\partial \pi(P^L)}{\partial \rho} = -\left[\overline{w} - w(P^L, \rho)\right] l[w(P^L, \rho)] < 0 \qquad (31)$$

Proposition three establishes that the profit if caught in non-compliance of a *Low* firm with a given productivity parameter is decreasing in the punishment parameter ρ implying that the government can increase/decrease the threshold productivity below which a firm can commit to being a *Low* firm by decreasing/increasing this parameter. Next we want to establish that there is a combination of policy parameters where no firm would reduce employment.

We continue by assuming that there is a continuous distribution of firms with productivity between $\underline{P}$ and $\overline{P}$ where $\underline{P}$ is the threshold below which a firm is a *Low* firm. We will use the notation l^* to represent the optimal choice of employment before a minimum wage is imposed and $\bar{l}$ to represent the optimal choice of employment for a compliant firm for either *High* or *Medium* firms in the proof below. We also assume that there is a minimum wage $\overline{w}$ and the pre-minimum wage labour supply curve defined earlier. We assume that the exogenous distribution of the firm's productivity distribution is over the range $P \in (\underline{P}, \overline{P})$ where within this range we will define the following four values for P as follows: $\underline{P} < P^0 < P^1 < P^2 < P^3 < \overline{P}$. We define P^1 the threshold value of productivity such that the firm's pre-minimum wage value of marginal product, which

equals the firm's marginal cost when the firm optimises, equals the minimum wage:

$$\overline{w} = w_l(l^*, P^1)l^*(l^*, P^1) + w(l^*, P^1) \tag{32}$$
$$= P^1 F_{\bar{l}}(\bar{l}, P^1) = P^1 F_{l^*}(l^*, P^1)$$

This condition is illustrated in Figure 6 for the case when the demand curve is linear. This just defines a productivity level such that the marginal cost of labour at the optimal choice of labour prior to the minimum wage equals the minimum wage for a firm with this productivity.

We define the productivity parameter P^3 as the threshold level above which a firm will be a *High* firm:

$$P^3 F_l[l(\overline{w})] = \overline{w} + \frac{l(\overline{w})}{l_w(\overline{w})} \tag{33}$$

If $P > P^3$, the value of marginal product of labour is greater than the marginal cost of labour at the number of workers who will supply labour at the minimum wage.[30] This condition is illustrated for a linear demand curve in Figure 7. Productivity in Figure B.1 is just high enough so that the wage the firm would optimally choose equals the minimum wage. If this condition holds the firm is a *High* firm and will be unaffected by the minimum wage as it will optimally choose to pay a wage in excess of the minimum wage.

Proposition four.

(a) Compliant firms with values of $P > P^1$ will choose employment greater than or equal to the level they chose prior to the minimum wage. For example, any firm with productivity P^2 such that $P^1 < P^2 < P^3$ will choose higher employment than the optimal employment level prior to the minimum wage.

(b) If $\lambda = 0$ and the punishment parameter ρ is set such that $\underline{P} = P^1$, then no firm will reduce employment in response to the introduction of the minimum wage.

   Proof:

(a) The pre-minimum wage profit function of a compliant firm with a given value for the productivity parameter is given as $\pi(w, P) = PF[l(w)] - wl(w, \lambda) \geq k$ and the labour supply curve

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[30]The total cost of labour is $w(l)l$ and the marginal cost of an extra worker evaluated at the minimum wage is $\overline{w} + \frac{l(\overline{w})}{l_w(\overline{w})}$.

from equation (2) is: $l = \frac{\psi(w-\bar{u})}{t}$. We also note that this can be inverted so that the wage can be written: $w^m = \frac{t}{\psi}l + \bar{u}$. For the purposes of this section we will allow the optimising firm to choose the number of workers (rather than the wage).[31] The pre-minimum wage optimisation condition for a firm with $P^1 \le P^2 < P^3$ is:

$$P^2 F_l(l) = w_l(l)l + w(l) \tag{34}$$

We also note totally differentiating this condition implies that:

$$\frac{dl^*}{dP} = \frac{F_{l^*}}{-P^2 F_{l^*l^*} + 2w_{l^*}} \tag{35}$$

The optimisation condition sets the value of marginal product equal to the marginal cost of labour for the last worker hired. The optimisation condition for a compliant firm is $P^1 < P^2 < P^3$:

$$P^2 F_{\bar{l}}[\bar{l}(P^2)] = \overline{w} \quad \text{if} \quad \bar{l}(P^2) \le l(\overline{w}) \tag{36}$$

If the productivity parameter has the value P^1 then by definition:

$$
\begin{aligned}
\overline{w} &= w_l(l^*, P^1)l^*(l^*, P^1) + w(l^*, P^1) \\
&= P^1 F_{\bar{l}}(\bar{l}, P^1) = P^1 F_{l^*}(l^*, P^1)
\end{aligned}
\tag{37}
$$

Since $\bar{l} = l^*$ for this firm and $\frac{dl^*}{dP} > 0$ it follows that at any $P^1 < P^2 < P^3$ pre-minimum wage employment is higher in the P^2 firm than the P^1 firm. Also, for the pre-minimum wage equilibrium, the derivative of the marginal cost of labour with respect to labour is positive $\left(\frac{\partial(w_l l^* + w)}{\partial l} = w_{ll}l^* + 2w_l = 2w_l > 0\right)$. That is the P^2 firm will have higher employment and higher marginal cost than the P^1 firm before the minimum wage is introduced. By contrast from equation (35), after the minimum wage the marginal cost for both the P^2 firm and the P^1 firm is the minimum wage $\overline{w}$. Since the P^2 firm optimises by setting marginal cost equal to the value of marginal product of labour before and after the minimum wage, it follows that the P^2 firm has higher marginal cost and higher value of marginal product before the minimum

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[31]The wage and employment choice are the same whether the firm optimises by choosing the wage (where labour supply is written as a function of the wage) or the level of employment (where the wage is written as a function of the number of workers). Optimising over the level of employment in this section makes the exposition a little easier.

wage than after. Since $F_{ll}(l) < 0$, the value of marginal product of labour is diminishing in employment, it follows that the P^2 firm increases employment when the minimum wage is introduced: $\bar{l}(P^2) > l^*(P^1)$. If $P \geq P^3$ the firm is a *High* firm and employment is unaffected by the minimum wage.

Similarly, for $P^0 < P^1$ since the change in pre-minimum wage employment from a change in productivity is positive ($\frac{dl^*}{dP} > 0$) and the change in the marginal cost of labour from a change in labour is positive $\left(\frac{\partial (w_l l^* + w)}{\partial l} = w_{ll} l^* + 2w_l = 2w_l > 0 \right)$. It follows by the same logic used above that $P^0 F_{\bar{l}}(\bar{l}, P^0) > P^0 F_{l^*}(l^*, P^0)$ implying that $\bar{l}(P^0) < l^*(P^0).$[32] That is any firm that complies with the minimum wage at values for the productivity parameter will choose lower employment under the minimum wage than prior to the minimum wage. It could be that for a firm with a value for the productivity parameter in this range that the minimum wage would make the firm unviable and shut down.

(b) The labour supply curve and profit function of a Low firm are given in equations (21) and (24). We see that these are identical to the labour supply curve and profit function of the firm if there were no minimum wage (i.e., $\lambda = 0$), so that the choice of wage and employment and the profit level of bad firms will be unaffected by the minimum wage. Inequality (31) in Proposition three shows that $\frac{\partial \pi(P)}{\partial \rho} < 0$ for *Low* firms. This implies that the government can increase ρ to a point such that $P^1 = \underline{P}$ and all firms with productivity such that they would lower employment in response to the minimum wage would stay in non-compliance and would not be caught since no worker would complain.

In Appendix B, we assume a linear labour demand curve and assume parameter values to solve the model explicitly, purely for descriptive purposes. We assume a value for the minimum wage and solve for the value of ρ such that no firm decreases employment in response to the minimum wage. Appendix D extends the example with a linear demand curve to the case where there are high and low skilled workers and where these workers are perfect substitutes. The analysis shows that the share of skilled workers is independent of the firm's productivity prior to the minimum wage. For firms that remain viable, if a minimum wage were rigorously enforced, the lower their productivity, the bigger the impact on low-skill employment. In particular, if they must comply, the lowest productivity firms would hire only high-skilled workers at the minimum wage and firms

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[32] P^1 is endogenous. In the equilibrium we will outline below the authorities will choose values of the policy parameters such that $P^1 = \underline{P}$. There will be no P^0 firms in equilibrium.

would only begin hiring low-skill workers when their productivity is high enough so that they are employing all of the high-skill workers they can attract at the minimum wage. As productivity increases firms would hire more low-skilled workers. In this sense, the policy of turning a blind eye to enforcement of the minimum wage is effectively turning a blind eye to low productivity firms. That is, low productivity firms that would remain viable, would choose to cut employment of low-skill workers at the minimum wage. We demonstrate, in this simple example, that if the authorities wish to prevent this employment loss, they can make the enforcement system based on worker complaints, commit to investigating these complaints at a high enough rate and make the penalties for non-compliance high enough so that workers in these firms will not complain. As a result, the firms will remain non-compliant and employment of low-skill workers in particular will be protected. It is important to state that while these observations are interesting, the example in Appendix D remains very simple as it imposes a lot of structure on the model.

5. Discussion and conclusion

The model outlined in this article leads to a strong conclusion that only firms who will have a non-negative employment response will comply with the minimum wage. The threat of inspection is only credible to high productivity firms because it is based on worker complaints and workers in low productivity firms cannot gain from compliance. We impose a lot of structure on the model to get the equilibrium outlined in the model above. The reality may be much more complex, but this simple framework demonstrates an underlying mechanism which is intuitive and plausible in our opinion. That is, to the extent that enforcement is based on worker complaints, workers in low productivity firms are less likely to complain given that stricter enforcement is more likely to lead to job loss and less likely to lead to any refund of underpayments of wages. Thus, low productivity firms are less likely to fear inspection making non-compliance relatively more attractive. Since low productivity firms are non-compliant and small, the model is also consistent with the empirical literature which finds a strong link between non-compliance and firm size. While we focus on a particular case where the authorities ensure no workers lose their job in response to the minimum wage, we outline a mechanism where authorities with different preferences can choose an appropriate combination of penalties and inspections in response to worker complaints such that firms above a given productivity level will comply with the minimum wage and the authorities will tolerate non-compliance for firms with lower productivity.

We noted earlier that we expect that there are many aspects of regulation and formality where

the arguments in the model would apply. Health and safety regulation, regulations around the length of hours worked and so on, where regulation benefits the worker at the expense of the firm. We have chosen to exclusively focus on the minimum wage for a number of reasons. Doing so makes the model more tractable, the minimum wage is pervasive as a policy and available data which allows us to document the degree of non-compliance, the nature of enforcement and the potential cost of compliance relative to productivity for informal firms. Of course another reason for doing this is that there is a large literature on non-compliance with the minimum wage which largely ignores the fact that many of the firms that employ non-compliant workers could not comply with the minimum wage and survive.

Of course we know from our survey of enforcement regimes that while enforcement regimes are primarily based on worker complaints, they often also have an element of inspection that is either random or based on particular sectors. We could easily imagine that a certain degree of non-complaint based inspections may be necessary to prevent an employer victimising employees for example. There may be other issues not captured by the model here which will give the labour inspectorate an incentive to inspect. One example would be if the inspectorate was concerned that there were undocumented migrants in a particular labour market where undocumented migrants would not have the same incentive to complain as native workers if they feared deportation, so that the mechanism described in this model where the threat of worker complaints prevent firms who can afford to comply from doing so. The framework we propose in this article is simple for other reasons. In particular, we assume that workers (i) know their employer's productivity and (ii) would never complain if they knew their firms would shut down. Of course, information may be much less perfect and workers decisions to complain in some cases may be coloured by other issues which may make them like or dislike their employer. Accepting these limitations, the model does demonstrate the potential power of worker complaints as a way of targeting enforcement. An alternative story is a simpler one where the authorities know who the small informal firms are and explicitly decide to ignore these firms in their inspection efforts. Indeed, our survey of enforcement mechanisms suggests that even when inspections are not based on complaints, they are still endogenous. The authorities tend to target particular sectors and groups of workers. If this is part of the story it leads to the same outcome as the model we outline. That is, low productivity firms have little to fear if they are non-compliant and are unlikely to reduce employment in response to the minimum wage.

Since the pioneering model of Ashenfelter and Smith (1979), the literature on non-compliance

surveyed earlier emphasises the importance of accounting for non-compliance in the way we model minimum wage firms. An implication of the model we develop in this article is that, even though there is widespread non-compliance, it may be that for high productivity firms non-compliance would lead to a very high probability of detection. For such firms, a simple model with full compliance may be a more appropriate way to model such firms rather than the common practice of using a model with a constant probability of being caught in non-compliance. For low productivity firms, if there is little chance of being caught in non-compliance, the appropriate model would be of a firm where there is no minimum wage. Our model contributes to this literature by providing a simple framework which allows to deal with both cases.

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Table 1: Statistics on minimum wage to productivity and the share of low productivity firms

|	Obs.	Minimum wage to productivity		Upper threshold Share of low productivity firms		Lower threshold Share of low productivity firms	
		Mean	SD	Mean	SD	Mean	SD
Total sample	15,952	0.713	1.606	0.175	0.380	0.252	0.434
Informal firms	6,045	1.341	2.188	0.342	0.475	0.484	0.500
Formal firms	9,907	0.330	0.920	0.073	0.261	0.110	0.313
FIRM SIZE							
1 worker	2,743	1.279	2.060	0.326	0.469	0.481	0.500
2-5 workers	4,034	1.125	2.064	0.284	0.451	0.400	0.490
6-10 workers	2,511	0.502	1.218	0.122	0.327	0.174	0.379
11-20 workers	2,075	0.359	0.906	0.082	0.275	0.116	0.320
21-40 workers	1,637	0.317	0.812	0.076	0.266	0.119	0.324
41+ workers	2,952	0.273	1.019	0.052	0.222	0.071	0.257

Note: Low productivity firms refer to those firms who have a ratio of minimum wage to productivity higher than 1 (*upper threshold*) and higher than 0.65 (*lower threshold*), respectively.

Figure 1: Cumulative distribution of the minimum wage to productivity
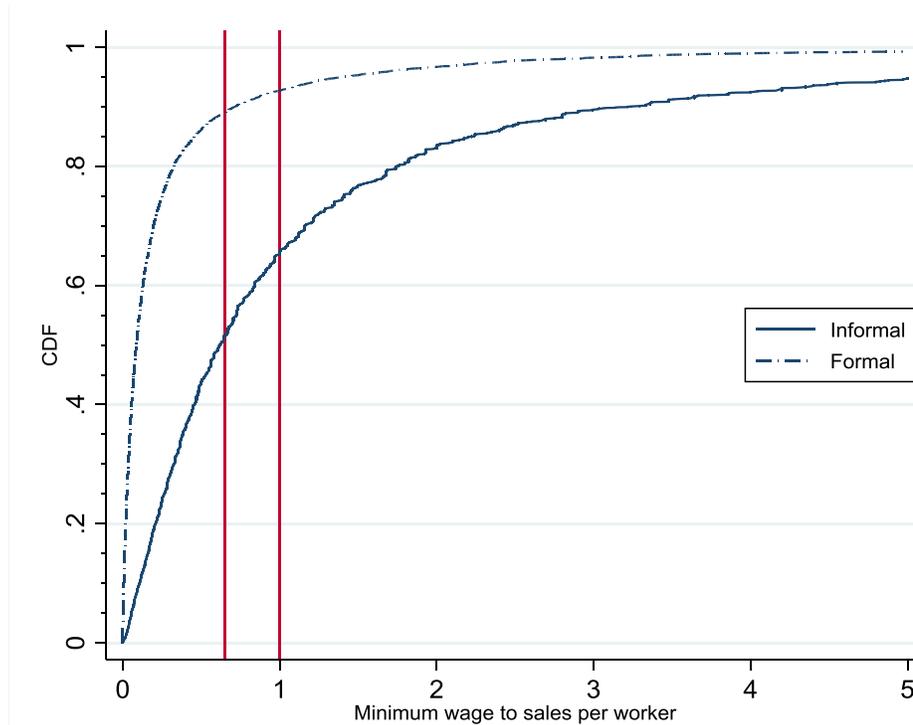

Note: Distributions are shown separately for the samples of informal (solid line) and formal (dashed line) firms. The vertical (red) lines indicate the cut-off levels of the minimum wage to productivity of 1 and 0.65. We calculate the CDF using all observations but only plot the values up to a value of 5 on the horizontal axis to make the graph easier to read at the cut-off values.

Figure 2: Cumulative distribution of the minimum wage to productivity, by country
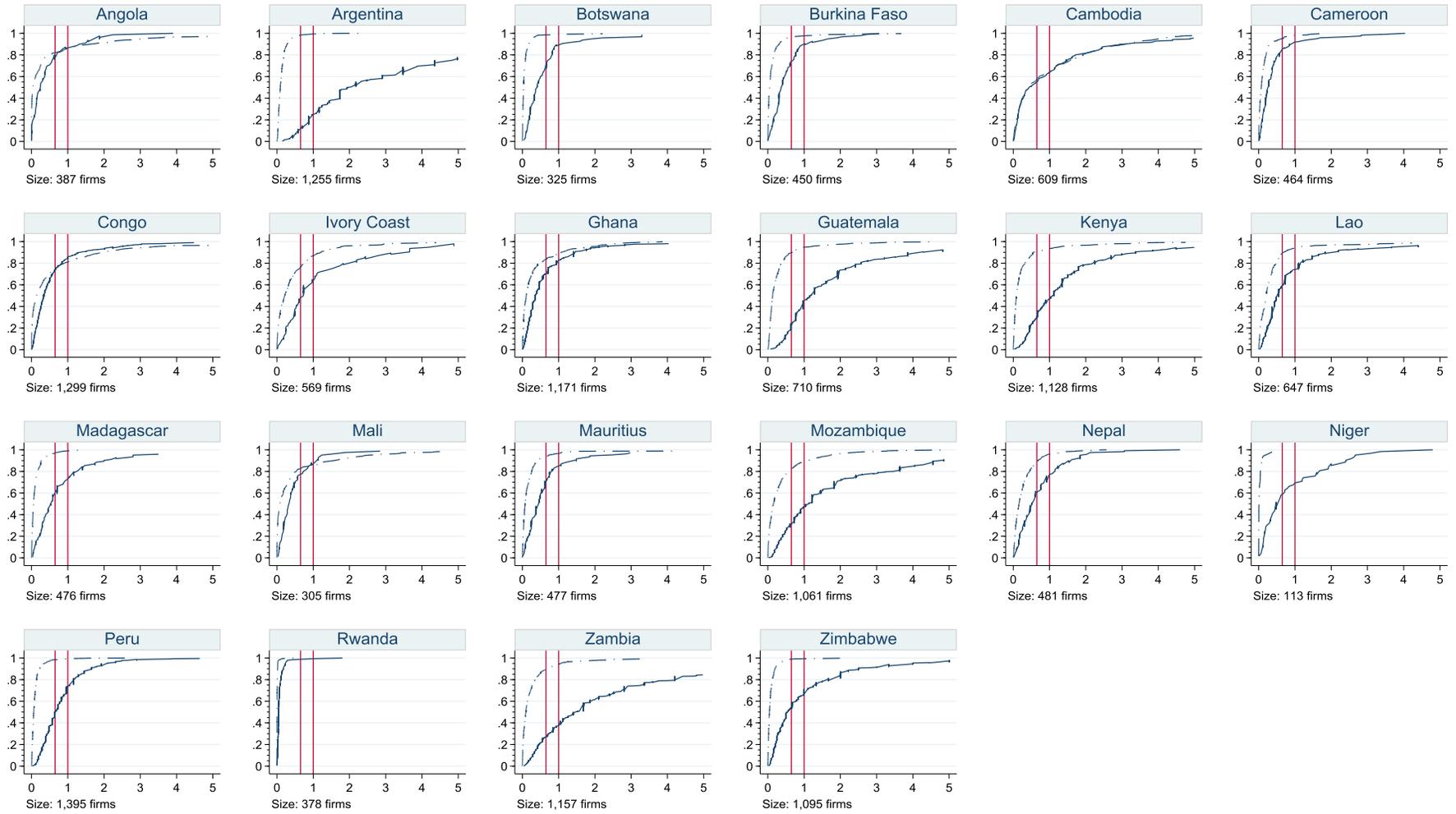
Note: Distributions refer to the sample informal (solid line) and formal (dashed line) firms in each country. The vertical lines indicate the cut-off levels of the minimum wage to productivity of 1 and 0.65. We calculate the CDF using all observations but only plot the values up to a value of 5 on the horizontal axis.

Figure 3: Fraction of workers in low productivity firms (informal vs. formal), by country
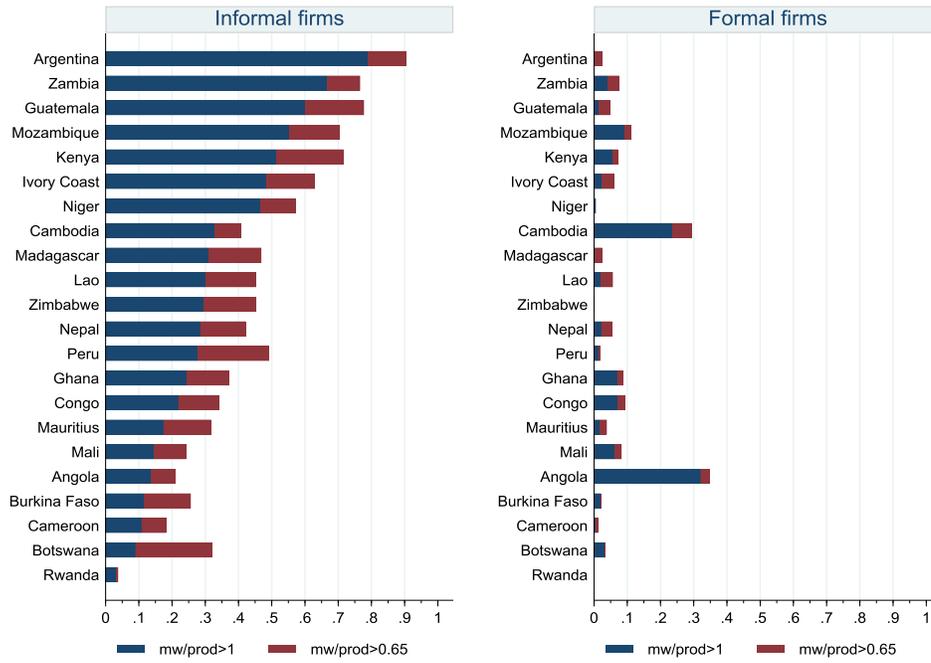
Notes: (i) For each country, we present the fraction of workers in low productivity firms, separately for the informal and formal sector, with respect to two cut-off points of the ratio of minimum wage to productivity, 1 and 0.65, respectively; (ii) The fractions with the cut-off point of 0.65 correspond to the sum of the blue and red bars.

Figure 4: Relationship between the average productivity and the average wage in informal firms
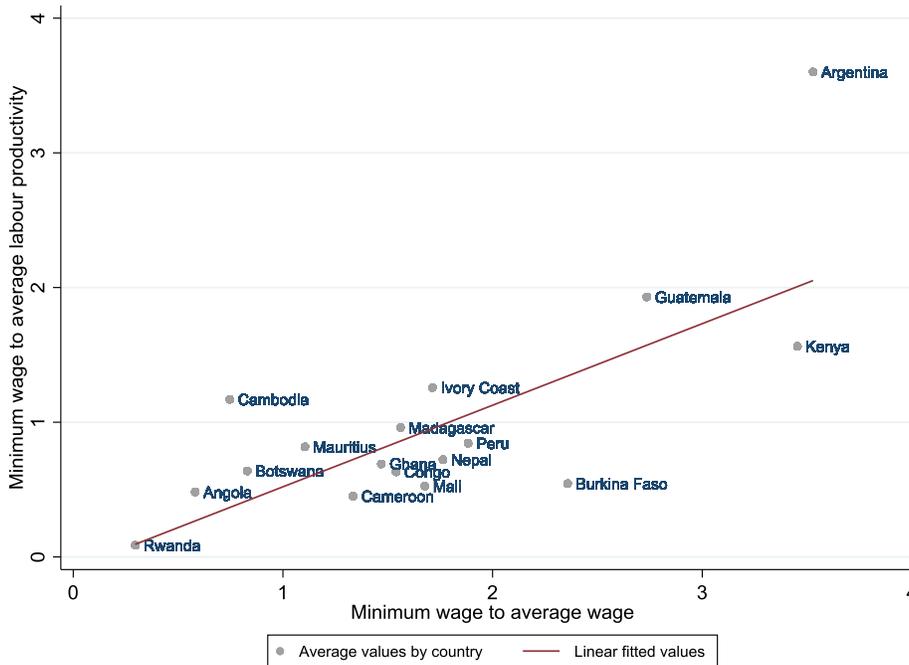
Figure 5: Box plot of minimum wage to average wage in the informal sector
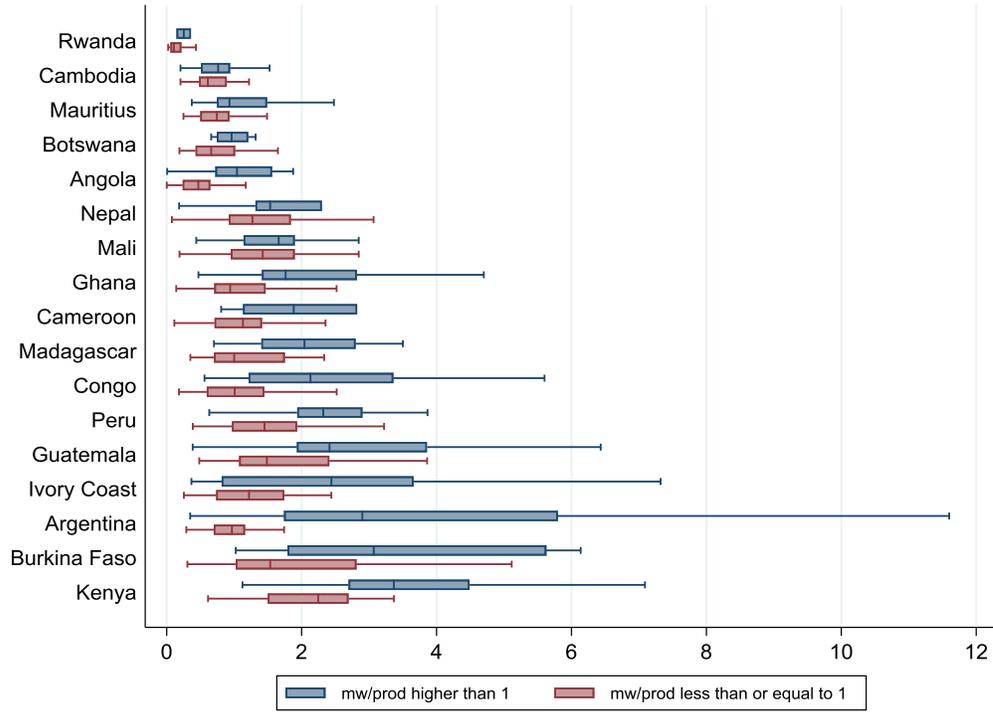
Note: We plot the minimum wage to average salary in informal firms, by country and firms' average productivity. This plot excludes outside values of few firms paying unusually low average salary with respect to legal minimum wage. Low productivity firms (blue boxes) are those with a minimum wage to productivity higher than 1 and medium/high productivity firms (red boxes) productivity firms (blue boxes) are those with a minimum wage to productivity lower than or equal to 1.

Table 2: Determinants of low productivity firms - Marginal effects

	Total sample			Informal firms		
	(1)	(2)	(3)	(4)	(5)	(6)
Informal dummy	0.188***	0.144***	0.107***			
	(0.007)	(0.009)	(0.012)			
(Log) firm size		-0.008***	-0.015***	0.129***	0.150***	0.151***
		(0.003)	(0.003)	(0.018)	(0.019)	(0.019)
Informal dummy x (log) firm size			0.030***			
			(0.006)			
(Log) Capital intensity		-0.043***	-0.042***	-0.192***	-0.175***	-0.177***
		(0.006)	(0.006)	(0.022)	(0.022)	(0.022)
Manufacturing activity		0.029***	0.026***	0.017	0.026	0.022
		(0.006)	(0.006)	(0.021)	(0.022)	(0.022)
Years of activity of the firm		-0.001***	-0.001***	0.000	0.000	0.000
		(0.000)	(0.000)	(0.001)	(0.001)	(0.001)
CITY SIZE						
Population over 1 million		0.015**	0.015*	0.010	0.023	0.020
		(0.008)	(0.008)	(0.029)	(0.029)	(0.030)
Population over 250.000 to 1 million		0.006	0.005	0.004	0.004	0.002
		(0.008)	(0.008)	(0.029)	(0.029)	(0.029)
Population over 50.000 to 250.000		0.009	0.006	0.121***	0.096**	0.092*
		(0.009)	(0.009)	(0.046)	(0.048)	(0.048)
Population less than 50.000		-0.016	-0.014	-0.115	-0.129	-0.132
		(0.017)	(0.016)	(0.089)	(0.089)	(0.088)
OWNER'S CHARACTERISTICS						
Woman					0.058***	0.056***
					(0.021)	(0.021)
Age					-0.025***	-0.025***
					(0.005)	(0.005)
Age squared					0.000***	0.000***
					(0.000)	(0.000)
Primary education level					0.012	0.010
					(0.044)	(0.044)
Secondary education level					-0.071	-0.073
					(0.044)	(0.045)
Vocational training					-0.151***	-0.154***
					(0.050)	(0.051)
University degree					-0.168***	-0.174***
					(0.058)	(0.058)
FIRM'S PREMISES AND INFRASTRUCTURE						
Within HH premises						0.039*
						(0.023)
Use electricity						-0.001
						(0.023)
Use water						-0.013
						(0.022)
Observations	**11,019**	**11,019**	**11,019**	**2,412**	**2,412**	**2,412**
Pseudo-R2	0.212	0.235	0.238	0.201	0.226	0.227

Notes: (i) Columns (1)-(3) refer to the total sample of firms and columns (4)-(6) refer to the sample of informal firms; (ii) We report average marginal effects from the probit estimation; (iii) Capital intensity is the capital amount (vehicles, machinery, tools) per unit of labour; (iv) Capital city is the reference category for the city size; (v) Country and year dummies are included; (vi) Robust standard errors in parentheses; (v) *** p¡0.01, ** p¡0.05, * p¡0.1.

Figure 6: The productivity threshold for no employment loss

Wage

A

Marginal Cost of Labour

Labour supply

$\bar{w}$

w

Labour demand $= P^1 F_l$

$\bar{l} = l^*$

Labour
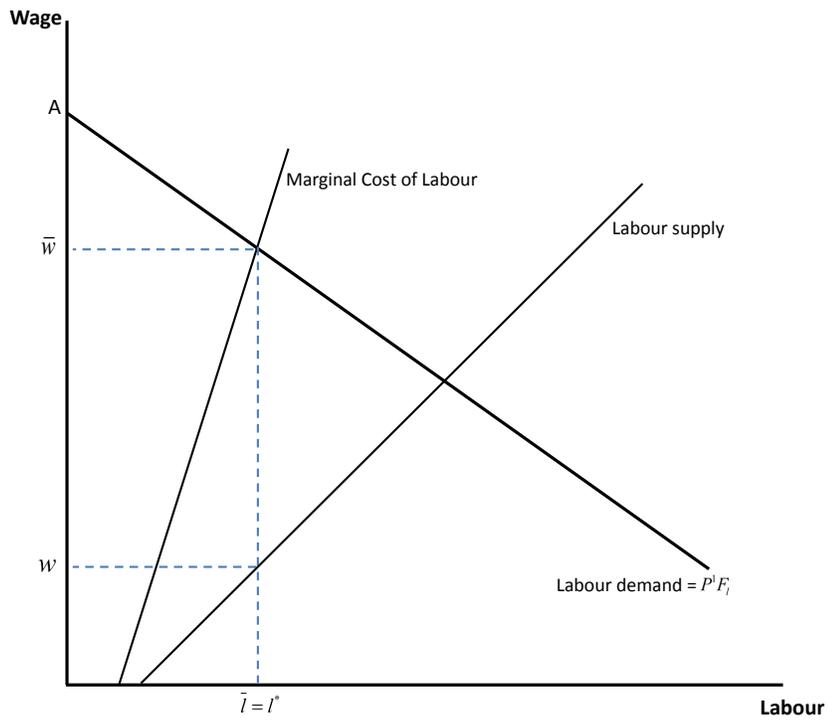
Figure 7: The productivity threshold for *High* firms

Wage

Marginal Cost of Labour

Labour supply

$w = \bar{w}$

Labour demand $= P^3 F_l$

$\bar{l} = l^*$

Labour

44
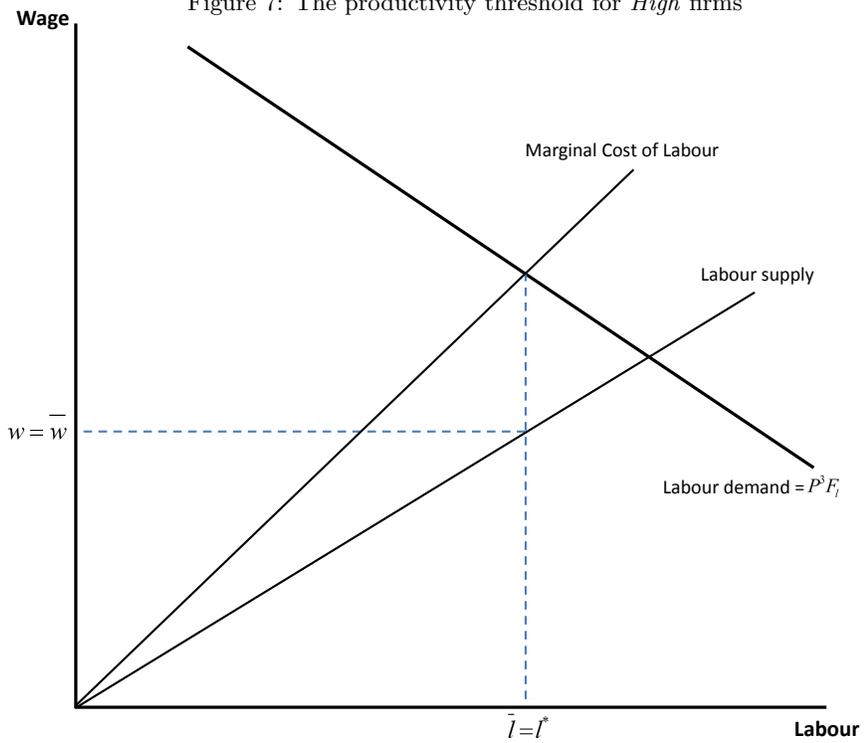
Appendix A

Country	Types of inspection visits and sanctions for non-compliance
Algeria	- Labour inspectors carry out ordinary visits, follow-up visits, and special visits for the purposes of an investigation. - Between 2000 and 2009, the budget for labour inspection increased by 120% (expanding the physical presence of inspectorates across the country and providing inspectors with an attractive salary and better equipment to carry out their work). This has led to an increase in visits from 82,000 in 2006 to 126,000 in 2009. - Under the legislation, an employer in breach of the law is fined between 1,000 and 2,000 Algerian dinars (equivalent to US$12.50 and US$25 respectively).
Angola	- Three types of inspection visits: (i) at the initiative of a worker, employer or other agencies or judicial authorities; (ii) as a result of prior planning; (iii) at the initiative of the inspector within other programs or activities. - If the labour inspector identifies irregularities, the employer is given a period of time to make corrections. If the infraction is not corrected, the inspector can impose a fine. If the payment is not made in time, the case is then filed with the Labour Court for enforcement proceedings.
Argentina	- A uniform system of fines, with minimum and maximum amounts adjustable at the discretion of the administrative authority. - Financial penalties increase with the number of repeat offences. - Failure to pay a fine is punishable by detention. - In the case of a repeat offence the establishment may be closed for up to ten days, while the workers retain their entitlement to remuneration.
Bahrain	- In July 2014, more than 6,000 establishments were inspected and 107 violations (involving approximately 400 employees) were recorded. - Over 50 companies were penalized with fines ranging from BD 500 to BD 1,000 (approximately USD 2,000).
Benin	The financial penalty increases in cases of repeat offences and is combined with a prison sentence of between 15 days and two months.
Bolivia	The amount of penalties is linked to the minimum wage: the fine is a multiple of the daily reference wage.
Botswana	- Workplace inspections are done as routine or spot checks. Spot checks are normally done in response to reports that are received from various stakeholders. - Employees and employers who experience violation of labour legislations are encouraged to file a complaint through the nearest labour office. Their identity remains anonymous. Labour inspectors are assigned to inspect on complaints.
Brazil	- Inspectors include in their planning enforcement actions in response to complaints from workers. Complaints involving immediate risk to the safety, health or to the remuneration of workers are immediately addressed. - Fines are classified into several categories including fixed, fixed per capita, variable and variable per capita. Fines can increase depending on the circumstances in which the inspection took place or in case of a subsequent violation.
Burkina Faso	Financial penalties increase with the number of repeat offences.
Cambodia	- Inspectors carry out routine visits and special visits which are generated by a request or complaint. - The amount of penalties is a multiple of the daily reference wage.
Cameroon	- The amount of the fine is multiplied by the number of workers affected.
Chile	- The amount of the fine varies depending on the size of the firm.
China	- Employers who are found to pay below the minimum wage must pay the difference.
Costa Rica	- Workers can initiate an inspection personally, by telephone or anonymously. - Enforcement is carried out by inspectors of the MoL and through the complaints made by workers to the National Directorate of Work Inspection.

	- Approximately 11% of the firms were inspected in 2000 and 2001 (some randomly and some as a result of a complaint). Infractions of the minimum wage were fourth in importance among the fourteen infractions listed. - Labour inspectors are not authorized to impose fines for labour law violations. A fine could be imposed if the violation persists. - The penalty for noncompliance is a relatively small fine. But employers must also pay up to two years of owed back pay to the worker.
Dominican Republic	- A graduated system under which the most serious violations (child labour or serious health and safety violations) are more heavily fined. - The highest possible fine is only 1,593 USD, which would have little impact on a large export factory or maquiladora.
Ecuador	- Unions reportedly act as important channels for the transmission of complaints. The seriousness of the violation and the firm's financial capacity are considered. - Decrees fixing minimum wages specifically establish penalties for non-compliance with their provisions. Penalties increase with the number of repeat offences.
Ethiopia	Inspection visits (generally unannounced) are both proactive and reactive. Fines can only be imposed by a court. Inspectors can only instruct the employer to remedy unlawful working conditions within a given period. If the employer does not improve the situation, the inspector can report the incident to the Ministry for guidance. Fines do not exceed 1,200 Birr (68 USD).
Fiji	- An employer found guilty of a violation has the choice between paying a fine set by the inspector and facing prosecution.
Gabon	- An employer who repeats an offence is liable to a financial penalty the amount of which is doubled or imprisonment of from two to six months, or both.
Guatemala	- In total, there were 8,785 labour dispute settlement interventions in 2008 as compared to 5,342 inspection visits. - The amount of fines is linked to the minimum wage: inspectors are empowered to impose penalties ranging from 2 to 14 times the monthly minimum wage (MW), depending on the gravity of the offence: (i) between 3 and 14 times the MW for agricultural activities; (ii) between 3 and 12 times MW when the violation concerns a mandatory provision; (iii) between 6 and 14 times the MW for violations of safety and health provisions; (iv) for any other violation, between 2 and 9 times the MW for firms and between 10 and 20 times the daily minimum wage for workers.
Haiti	- Employer who violates provisions of the Labour Code shall be punished by a fine between 200 to 2,000 Haitian Gourdes (HTG) (5 to 50 USD) or imprisonment from 15 days to three months. In cases of repeat offences, fines may be doubled. - These sanctions may only be imposed by the Labour Court.
Honduras	- Two types of work inspections are carried out: special and scheduled. - Special visits respond to a verbal or written request from a worker and scheduled visits are initiated ex officio. - The central work of the inspection is oriented to carrying out special inspections, mainly dealing with individual and, to a lesser extent, collective claims. - Given the poor economic and human resources and the lack of a business registry, there is practically no schedule of inspection activities. The Directorate of Salaries in the MoL had only four inspectors available to follow up on complaints and carry out random inspections for the entire country. - Fines range from 100 to 1000 Lempiras (5 to 52 USD) for failure to pay the minimum wage. Financial penalties increase with the number of repeat offences. - Fines to employers can be stiff: up to 2 years back pay of the difference between the worker's salary and the MW plus 100-600 Lempiras (which is approximately 5−32, using 2006 exchange rates), depending on the characteristics of the employer. - However, it is unlikely that very small employers are able to pay these fines. Not surprisingly, and given scarce resources, the inspectors focus enforcement efforts almost entirely on larger firms.
India	- Most inspections are conducted after receiving a complaint or in cases where it is deemed necessary to ensure the safety of workers.

	- Since 2008 and to reduce routine inspections, firms employing less than 40 workers are required to submit a self-certificate certified by a chartered accountant.
	- In the Indian State of Maharashtra, a novel labour management system (LMS) is created which allows workers to lodge complaints online.
	- Inspectors' sanctioning powers are limited to filing prosecution complaints.
	- Sanctions for violations of labour laws provide for fines and/or imprisonment.
Indonesia	The majority of inspection visits are planned visits; the remainder take place as the result of a complaint or accident notification. Labour inspectors, in case of non-compliance with the labour law, issue an order to employers. If the situation is not fixed, the inspector may file a case with the court.
Iraq	- In 2010, a total of 38 inspection boards carried out daily inspection visits and performed more than 1,000 inspection visits.
	- The seriousness of the violation and the firm's financial capacity are taken into account. The employer must pay the worker concerned double the difference between the wage paid and the minimum wage.
Iran	- For each underpaid worker, the employer is liable to a fine, the amount of which varies depending on the number of workers affected by the offence.
Jordan	- Labour inspectors carry out several types of inspection visits: routine visits, follow-up visits and special visits in response to complaints or occupational accidents.
	- In 2006, a free hotline (serving migrant workers in multiple languages) was installed to provide advice to workers and to enable them to submit complaints and report law violations to the MOL. The hotline registered 892 complaints in 2013.
	- A firm may be closed if it fails to respect compliance order issued by an inspector.
Kazakhstan	- Visits are either planned or as a response to complaints from individuals, legal entities or state authorities. Anonymous allegations do not constitute grounds for an unplanned inspection. Follow-up visits to check compliance are rare.
	- The amount of penalties is linked to the minimum wage: the fine is a multiple of the daily reference wage. An firm's first offence is sanctioned by a fine amounting to either five to ten times the minimum monthly wage (for small and medium-sized enterprises), or 20 to 25 times the minimum monthly wage (for large enterprises).
	- For repeat violations within a year, this figure increases to between 15 and 20 times the minimum monthly wage (for small and medium-sized enterprises), and between 25 and 30 times (for large enterprises).
Kuwait	- Since 2010 a hotline for residents to report violations is operational.
Kenya	- The selection of workplaces for inspection is planned every week based on the monthly performance contract targets in addition to individual complaints.
	- Fines can only be imposed by a court. Labour inspectors are not legally empowered to impose on-the-spot fines.
Lebanon	- Two types of inspection visits: periodic inspections and urgent (mainly complaint-based) inspections.
	- In 2010, the MoL (i) inspected 12,721 firms, employing approximately 300,000 workers; (ii) conducted 2,000 routine inspection visits per year at national level; (iii) issued warning letters to 75% of the visited enterprises.
	- Coverage of inspected enterprises remained less than 2% and only 0.5% of warnings resulted in penalizing employers or imposing fines. The enormous number of complaints registered exceeded its capacity to handle them.
	- Any person violating the Labour Code is liable to a fine between 250,000 and 2,500,000 Lebanese Pounds (167 to 1,668 USD) and a sentence of imprisonment ranging from one to three months, depending on the severity of the violation.
	- Inspectors cannot directly impose sanctions. Inspectors must first give employers a written warning and a deadline for compliance.
Mexico	- The penalty varies depending on the amount of underpaid wages.

Montenegro	- There is extensive legislation on monetary fines for labour law infractions. In 2008, the Labour Law set fine for employers at 10 to 300 times the minimum wage and 1.5 to 20 times the minimum wage for persons acting on behalf of the employer. On-the-spot pecuniary fines as 3 times the minimum wage. The law sets the penalty for employees at 1.5 to 20 times the minimum wage. The Law on Labour Inspection sets penalties at 50 to 200 times the minimum wage for the employer.
Morocco	- There are several types of inspection visits. Importantly, inspectors proceed for requested visits that are made at the request of the employees or the unions, the employer, or in collaboration with other institutions. - Unions reportedly act as important channels for the transmission of complaints regarding violations of labour regulations.
Mozambique	- The amount of the fine (between five and ten times the minimum wage) depends on the seriousness of the violation.
Namibia	- Labour inspectors carry out routine and complaints based visits. According to the government, every workplace should be subject to a routine visit once per year. - In cases of non-compliance, labour inspectors may issue (i) compliance orders which can be appealed to the Labour Court within 30 days, (ii) directions to the employer to pay the remuneration due and post notices where required.
Nepal	- Inspectors do not have prosecution authority.
Nicaragua	- One type of inspection visits are "Extraordinarias" when the inspector makes an inspection at the request of a party by virtue of a conflict or complaint. - Fines are reduced by 50% in cases involving small and medium-sized enterprises.
Niger	- Financial penalties increase with the number of repeat offences.
Oman	- Sanctions may be financial, administrative or criminal. - A fine not exceeding 100 OR (about 260 USD), multiplied by the number of affected workers, for employers violating workers' rights related to wages.
Palestinian Territory	- Progress has been noted in reference to the implementation of the minimum wage. While compliance with the minimum wage remains weak, labour inspectors pay attention to female-dominated sectors (care and textile sectors) where wages are very low. - Due to the limited scope of labour inspections, follow-up inspections on minimum wage compliance are largely based on individual complaints, and many women are hesitant about complaining for fear of losing their jobs.
Panama	- The amount of the fine doubles with the number of repeat offences.
Peru	- The legislation on labour inspection guarantees since 2004 the confidentiality of complaints. - The fines are considered to be quite low and do not usually exceed 57 USD per violation.
Philippines	- There are five different types of inspection visits: (1) Routine or regular inspections; (2) Complaint/referral inspection; (3) Imminent danger investigations; (4) Accident investigations; (5) Spot-checks. - Regional inspection offices and inspectors are required to carry out 6 inspection visits per week over 10 months (approximately 250 visits per inspector per year). - Labour inspectors have the power to issue compliance orders to give effect to the labour standards based on their findings in the course of inspection.
Saudi Arabia	- Labour inspection visits are classified as (i) comprehensive visits, (ii) follow-up visits, (iii) special visits in response to a complaint or accident, or (iv) occupational safety and health inspection visits.
South Africa	- Inspections are either proactive or reactive. - Inspections focus on particular economic sectors and devote a considerable extent to the provision of advice and education, through successive follow-up visits. - Fines can only be imposed by a court. The amount of fines gradually increases based on the number of repeat offences.
Sri Lanka	- Programmed visits and visits that arise from complaints. - The employer also pays an additional fine for each day for which the violation continues after conviction.
Syria	- Most of the inspection visits, including the planned ones, are based on complaints and rarely routine.

	- Sanctions are very low and ineffective in preventing firms from violating the law. - Fines range from 500 to 1000 Syrian Pounds (SYPs) (8 USD -15USD). These fines may be doubled, depending on the severity of the violation. In extreme cases, suspension of production can be ordered by the Minister.
Tanzania	- Most inspections are routine or planned visits. Only around 10% are based on worker complaints. - Enterprises are informed that a routine inspection will be conducted. By contrast, inspections based on worker complaints are conducted unannounced. - In 2008, inspectors carried out approximately 3,500 inspections. Fines can only be imposed by a court.
Thailand	- Many visits are carried out after denunciations received from workers and civil society organizations who inform of relevant facts and critical situations.
Togo	- Employers who repeat offences incur an increased fine and a prison sentence of between ten days and one month.
Tunisia	- The amount of the fine doubles with the number of repeat offences.
United Arab Emirates (UAE)	- Labour inspectors receive the workers' comments and complaints and refer them to the concerned departments and authorities. - The MOL established a fully computerized hotline service, which receives complaints and enquiries from national and migrant workers in 13 languages. The toll-free hotline is operated 15 hours daily from Saturday to Thursday. The hotline received 527,521 calls in 2009. - According to the MoL, inspection visits in 2008 and 2009 found 8,550 and 17,107 violations, respectively. As a result of these violations, 245 and 355 employers were prosecuted in 2008 and 2009, respectively. - In case of any labour law violation, sanctions may be up to 10,000 UED (2,730 USD) and/or up to six months in prison.
Uganda	- The approach to labour inspection is more reactive than proactive. In general, labour officers, whether at the central level or in the districts, spend the bulk of their time dealing with complaints brought by workers related to unfair dismissal, unpaid wages and workers' compensation. - In the districts, inspection visits are carried out infrequently if at all.
Uruguay	- The employer may be ordered to pay damages of up to 50% of the wages owed.
Venezuela	- The amount of penalties is linked to the minimum wage: the fine is a multiple of the daily reference wage.
Vietnam	- Visits are based on annual inspection work plans and/or denunciations received from workers. Inspections visits are all previously announced. - There is a greater emphasis on enforcement measures as well as responding on a case-by-case basis to complaints and denunciations. - Labour inspectors are empowered by law to enforce labour legislation through the use of sanctions.
Yemen	- The country has no comprehensive national labour inspection policy or strategy. At regional level, labour inspections are decided randomly on a daily basis without any supervision by the central authority. - In practice though, the high-risk sectors, mainly small and medium enterprises (which form the majority of existing enterprises in the country) are never visited by the labour inspectors. - Fines range between 500 and 20,000. Yemeni Rial (YRS) (1 to 93 USD). The law also provides for a period of imprisonment up to a maximum of three months.
Zambia	- Inspectors decide by themselves when and which companies to inspect, which was usually limited inspection to enterprises that were easily accessible. - Inspections are neither regularly nor systematically undertaken due to the lack of an in-house planning and monitoring mechanism. - The number of inspections per month per inspector is below the international norm of 20 per month.

Sources: Gindling and Terrell (2007, 2009); Gindling et al. (2015); ILO (2006, 2011, 2014a,b, 2016); Squire and Suthiwart-Narueput (1997); Vega Ruiz (2009); Vega Ruiz and Robert (2013).

Appendix B - An example with linear labour demand

We assume the following production function:

$$F(l) = Al - \frac{al^2}{2} \text{ so } F_l(l) = A - al \text{ and } F_{ll}(l) = -a \tag{B.1}$$

We assume no random inspections i.e. $\lambda = 0$, and solve for the threshold level of productivity such that no firm will decrease employment and for the level of ρ which will ensure that $P^1 = \underline{P}$.

The profit of a *Low* firm after being caught in non-compliance, as in Equation 23, is negative and given by:

$$\pi(P) = PF[\bar{l}(P)] - \overline{w}\bar{l}(P) - \rho[\overline{w} - w(P,\rho)]l^1[w(P,\rho)] < 0 \quad \text{where} \quad \bar{l} \leq l(\overline{w}) \tag{B.2}$$

The firm will comply with the minimum wage after being caught and will choose employment to satisfy: $PF_l(\bar{l}) = P(A - a\bar{l}) = \overline{w}$ so that $\bar{l} = \frac{A - \left(\frac{\overline{w}}{P}\right)}{a}$. We also know that with $\lambda = 0$, before being caught this *Low* firm's optimisation problem would be unaffected by the minimum wage so that the first order condition as in equation (24) is:

$$PF_l(l) = 2w - \overline{u} = P(A - al) \tag{B.3}$$

Inserting the labour supply curve, equation (40) can be written as:

$$P\left[A - a\frac{\psi(w - \overline{u})}{t}\right] = 2w - \overline{u}$$

This in turn can be simplified to solve for the wage:

$$w^1 = \frac{AtP + (a\psi P^1 + t)\overline{u}}{2t + a\psi P^1} \tag{B.4}$$

Next we insert the wage into the labour supply curve and simplify to get:

$$l^1 = \frac{\psi(AP^1 - \overline{u})}{2t + a\psi P^1} \tag{B.5}$$

If a firm with productivity parameter P^1 chooses the same employment after the minimum wage as before, it must be that the minimum wage equals the marginal cost of employment at the pre-minimum wage level of employment, as illustrated in Figure 7.

The marginal cost of labour is:

$$MC = l + \frac{\partial l}{\partial w} w = \frac{2\psi w - \overline{u}}{t} \tag{B.6}$$

The firm with $P = P^1$ will have marginal cost of labour equal to the VMP minimum wage so that: $MC = VMP = \overline{w}$. Using optimal employment above in the second of these equalities (where P^1 is given) we can solve for the minimum wage as the value of marginal product:

$$\overline{w} = P^1(A - al) = P^1 \left\{ A - a \left[\frac{\psi(AP^1 - \overline{u})}{2t + a\psi P^1} \right] \right\} \tag{B.7}$$

Next we know that the firm with productivity parameter P^3 the minimum wage will be the firm's optimal wage. So if we solve for labour supply at the minimum wage above:

$$l^3 = \frac{\psi(\overline{w} - \overline{u})}{t} \tag{B.8}$$

The value of marginal product at this level of employment equals the marginal cost of this level of employment (we evaluate marginal cost in terms of the wage here):

$$P^3(A - al^3) = P^3 \left[A - \frac{a\psi(\overline{w} - \overline{u})}{t} \right] - \frac{\partial w}{\partial l} + w = \frac{\psi(2\overline{w} - \overline{u})}{t} \tag{B.9}$$

We can solve for P^3 and the Value of marginal product of the *High* firm respectively as:

$$P^3 = \frac{\psi(2\overline{w} - \overline{u})}{tA - a\psi(\overline{w} - \overline{u})} \tag{B.10}$$

Figure B.1 below plots the solution where $P^1 = \overline{u} = \psi = t = a = 1$ and $A = 100$. The figure on the left plots the labour supply and marginal cost where the solution for the minimum wage is $\overline{w} = 67$. We see on the left hand side graph that given the parameter assumptions above, this minimum wage is such that the wage and employment level the firm would have chosen before the minimum wage ($w = 33.1$ and $l = 33$) is the same as the employment level the firm would choose at the minimum wage. The figure on the right solves for the value of the productivity parameter for the *High* firm $P^3 = 3.91$ such that the firm would choose a wage equal to the minimum wage, so that the minimum wage will have no impact on this firms wage or employment which is at $l = 66$.

Next we need to solve for ρ such that a firm with productivity P^1 will have the incentive to shut down if caught in non-compliance. We can solve for this imposing a linear demand curve in

equation (1.39) and imposing the solutions for l^1, w^1 and the minimum wage (1.41), (1.42) and (1.44). We note in particular that $l^1 = \bar{l}$ for a firm with productivity P^1 when we calculate the solution. Setting this profit function equal to zero can solve for $\rho = \rho^*$.

$$
\begin{aligned}
\rho &= \left[\frac{P(A - \frac{a}{2}l^1) - \overline{w}}{\overline{w} - w}\right]\frac{\bar{l}}{l^1} = \frac{P(A - al^1) - \overline{w} + \frac{a}{2}l^1}{\overline{w} - w} = \frac{\frac{a}{2}l^1}{\overline{w} - w} \quad\quad\text{(B.11)}\\
&= \frac{\frac{a}{2}\frac{\psi(AP^1 - \overline{u})}{2t + a\psi P^1}}{P^1\left[A - a\left(\frac{\psi(AP^1 - \overline{u})}{2t + a\psi P^1}\right)\right] - \frac{AtP + (a\psi P^1 + t)\overline{u}}{2t + a\psi P^1}}\\
&= \frac{\frac{a}{2}\frac{\psi(AP^1 - \overline{u})}{2t + a\psi P^1}}{\frac{P^1A2t + P^1Aa\psi P^1 - P^1a\psi AP^1 + P^1\psi a\overline{u} - AtP - a\psi P^1\overline{u} - t\overline{u}}{2t + a\psi P^1}}\\
&= \frac{\frac{a}{2}\psi(AP^1 - \overline{u})}{P^1A2t + P^1Aa\psi P^1 - P^1a\psi AP^1 + P^1\psi a\overline{u} - AtP - a\psi P^1\overline{u} - t\overline{u}}\\
&= \frac{\frac{a}{2}\psi(AP^1 - \overline{u})}{t(AP^1 - \overline{u})}\\
&= \frac{a\psi}{2t}
\end{aligned}
$$

For the parameter assumptions we made above $\rho = \frac{a\psi}{2t} = \frac{1}{2}$.

Figure B.1: The linear example

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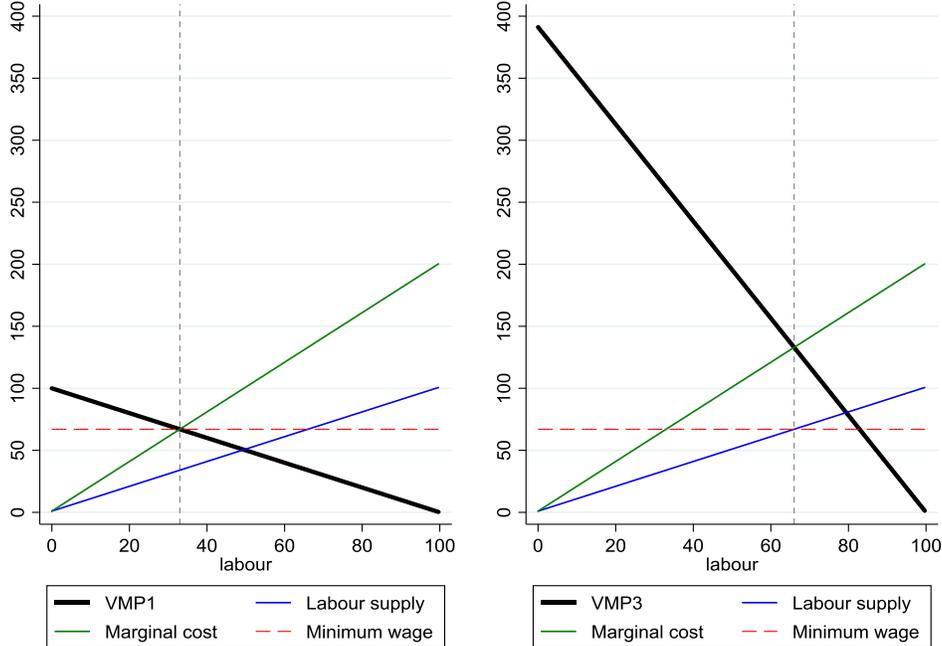
Appendix C - Imperfect information on productivity

For simplicity, we will assume that workers and firms are risk neutral. We will assume that workers observe a noisy signal of firm's productivity $\widehat{P} = P\varepsilon$ where P is the true level of productivity and ε is a random error term with expected value of one which is distributed over the range $\varepsilon \in (\underline{\varepsilon}, \overline{\varepsilon})$ where $\underline{\varepsilon}$ is the lowest possible value and $\overline{\varepsilon}$ is the highest possible value. In this case, some workers in *Low* productivity firms would have an overoptimistic view on their firm's productivity and could issue complaints raising the possibility that a firm could be examined and shut down. We would not expect the firm to be able to observe each of the workers realisations of ε, but we could assume that the distribution of ε is the same for each worker and is known to all workers and firms as well as to the government.

Let the distribution of productivity be uniform over the range $(\underline{P}, \overline{P})$. We note that all firms are within this range. Thus, if P^l is the value of the productivity parameter above which a firm is a *Medium* firm, then whenever a worker sees an observation of productivity such that $\widehat{P} = P\varepsilon > P^l\overline{\varepsilon}$, the signal of productivity is high enough such that the worker is certain the firm is a *Medium* firm. That is there are a range of productivity values ,where the firms productivity is so high that even with the highest possible distortion in the productivity signal, it would be clear to the worker that this is a *Medium* firm. For illustrative purposes we could assume that $\overline{P} = 1$, $\underline{P} = 0.5$, $\overline{\varepsilon} = 1.1$, $\underline{\varepsilon} = 0.9$ and $P^l = 0.7$. In this case, if the workers observed a signal of productivity $\widehat{P} > 0.7 \times 1.1 = 0.77$ they would be certain that the firm was not a *Low* firm. Similarly, if $\widehat{P}\varepsilon < P^l\underline{\varepsilon} = 0.7 \times 0.9 = 0.63$, the signal of productivity is low enough such that the worker can be certain that the firm is a *Low* firm. That is the productivity signal is so low that it is clear that even with the maximum distortion in the signal the worker receives, that this is a low firm. The implication is that even if the signal of productivity the worker receives is imperfect in this way, it will only be for firms that send productivity signals in the range $P^l\underline{\varepsilon} < \widehat{P} < P^l\overline{\varepsilon}$ (between 0.77 and 0.63) such that workers will be uncertain whether the firm is *Low* or *Medium*.

For a worker who observes a given signal of productivity $\widehat{P}$ in this range, there will be a probability q that the error term ε is large enough so that $\widehat{P} = P\varepsilon > P^l$ but $P < P^l$. In this case, the firm is not in fact viable even though the signal of productivity indicates that the firm is a *Medium* firm, in fact it is a *Low* firm. For illustrative purposes, we could assume that ε has a uniform distribution centred on unity, i.e. $\overline{\varepsilon} > 1$ and $\underline{\varepsilon} < 1$, so that the probability distribution function is $\frac{1}{\overline{\varepsilon} - \underline{\varepsilon}}$ and calculate the probability of this type of error. Given the firms signal of productivity, the ε that would put the firm at the threshold between being a *Low* and *Medium* firm is $P\varepsilon^* = P^l$. The

probability that ε lies in the range where the firm is in fact *Low* given the signal is $q = \frac{\overline{\varepsilon} - \varepsilon^*}{\overline{\varepsilon} - \underline{\varepsilon}}$. This means that, for a given worker who observes a signal $\widehat{P} = P\varepsilon < P^l\overline{\varepsilon}$ of productivity, the probability that the firm is not viable is $q = \frac{\overline{\varepsilon} - \varepsilon^*}{\overline{\varepsilon} - \underline{\varepsilon}}$ and the probability that the firm is viable is $1 - q = \frac{\varepsilon^* - \underline{\varepsilon}}{\overline{\varepsilon} - \underline{\varepsilon}}$.

The point in this example is that while we expect workers may have an imperfect signal of their employees productivity, if the signal employers receive is not too noisy, it may well be that it is good enough that many workers know for sure whether the firm they are employed in would stay in business, or not if caught in non-compliance.

Appendix D - Differences in worker ability

We assume there are two skill types of workers, High and Low skill. The mass ψ^i of workers of any firm's skill type i is uniformly distributed along a unit interval. The reservation utility of any skill type i is $\overline{u}_i$. The production function is:

$$F(l_1 \ldots l_a) = \sum_{i=1}^{2} A_i l_i - a \frac{\left(\sum_{i=1}^{2} l_i\right)^2}{2}$$

where l_i is the number of workers in skill category i. We assume that $A_2 > A_1$ such that A_1 is the low-skill group. We note that the marginal productivity of any skilled/unskilled worker is:

$$F_{l_i} = A_i - a \sum_{i=1}^{2} l_i$$

This framework is simple in that we effectively assume that each worker type is a perfect substitute for other types, yet there is diminishing marginal productivity for each worker type. Each skill group has a separate labour supply curve. This simple framework will allow us to see how non-compliance may be concentrated in lower skill groups. The labour supply curve and the inverse labour supply curve facing every firm for low and high skill workers are respectively:

$$l_i = \frac{\psi(w_i - \overline{u}_i)}{t} \qquad \text{and} \qquad w_i = \frac{tl_i + \overline{u}_i\psi}{\psi} \tag{D.1}$$

The labour supply curve is the same as it was in the analysis with one skill group except that we allow higher skill types to have higher outside options. The marginal cost of any labour type is:

$$MC_i = \frac{2w_i - \overline{u}_i}{t} = \frac{2tl_i + \overline{u}_i\psi}{\psi t} \tag{D.2}$$

We will assume that the relative values of the productivity parameter A_i between low and high skilled workers is the same as the relative value of the outside option. That is, there is a parameter θ such that $A_i = \theta_i A$ and $\overline{u}_i = \theta_i \overline{u}$. The profit maximising condition where marginal cost equals the value of marginal product for any group i is:

$$PA_i - Pa \sum_{j=1}^{2} l_j - \frac{\overline{u}_i}{t} - \frac{2}{\psi} l_i = 0$$

The equilibrium level of employment in a given firm with productivity parameter P for each group i can be solved as a function of the other group j:

$$l_i = \frac{\psi}{Pa\psi + 2}(PA_i - \frac{\overline{u}_i}{t}) - \frac{\psi}{Pa\psi + 2}Pal_j \tag{D.3}$$

Employment in any group can be solved as:

$$
\begin{aligned}
l_i &= \frac{\psi}{Pa\psi + 2}(PA_i - \frac{\overline{u}_i}{t}) - \frac{\psi}{Pa\psi + 2}Pal_j \\
l_j &= \frac{\psi}{Pa\psi + 2}(PA_i - \frac{\overline{u}_i}{t}) - \frac{\psi}{Pa\psi + 2}Pal_i \\
l_i &= \frac{2\psi(PA_i - \frac{\overline{u}_i}{t})(Pa\psi + 2)^2}{(Pa\psi + 2)^2 - (Pa\psi)^2} = \frac{\psi(PA_i - \frac{\overline{u}_i}{t})(Pa\psi + 2)^2}{Pa\psi + 2} = \psi\theta_i \left(PA - \frac{\overline{u}}{t}\right)(Pa\psi + 2)
\end{aligned}
\tag{D.4}
$$

In this case, the share in employment of any skill group in a firm with productivity P is given by:

$$\frac{l_i}{l_i + l_j} = \frac{\theta_i}{\theta_i + \theta_j}.$$

That is, the employment share is independent of the firm's productivity prior to the minimum wage.

Employment share is higher for the higher skill group. This suggests that if higher productivity firms are more likely to be compliant with the minimum wage, then lower skill groups will be more likely to work in non-compliant firms. In what follows, we will work through an example with two skill groups to see if this turns out to be true in this case[33]. The wage of any skill group $w_i = \frac{tl_i + \overline{u}_i \psi}{\psi}$ can be solved as:

$$w_i = \frac{tl_i}{\psi} + \overline{u}\theta_i = \theta_i \left[\psi(PAt - \overline{u})(Pa\psi + 2) + \overline{u}\right] \tag{D.5}$$

---

[33]Of course, it may be that there are some firms with some workers at the minimum wage and some workers below (Bhorat et al., 2015) in which case firms cannot be categorised as compliant or non-compliant.

At the margin, the firm will hire workers in the skill group with the biggest gap between the value of marginal product and the marginal cost of labour. This gap is given below for each skill type:

$$VMP_1 - MC_1 = PA_1 - (Pa + \frac{2}{\psi})l_1 - Pal_2 - \frac{\overline{u}_1}{t} \tag{D.6}$$

$$VMP_2 - MC_2 = PA_2 - (Pa + \frac{2}{\psi})l_2 - Pal_1 - \frac{\overline{u}_2}{t}$$

Next, we will contrast the case above where firms choose the wage and level of employment with the case when there is a minimum wage. We note that high-skill workers always have higher marginal productivity than low-skill workers $F_{l_2} - F_{l_1} = PA(\theta_2 - \theta_1)$. It follows that a firm where the minimum wage is binding for high-skill workers will always prefer to hire high-skill workers over low-skill workers since the marginal cost, that is the minimum wage, is the same for both skill groups. This means that any firm paying the minimum wage will hire high skill workers until either their marginal productivity equals the minimum wage or else until they employ the number of high ability workers they can attract at the minimum wage. After employing all high-skill workers supplying labour at the minimum wage, the firm will then consider hiring low-skill workers. That is, as long as their productivity is higher than the minimum wage.

We begin by establishing a series of thresholds for the productivity parameter where we can see what the impact on firm employment will be if the authorities enact penalties and a commitment to inspections such that firms above the threshold will be compliant and below will not be. For the first threshold, a firm with a value below the threshold would hire only high-skill workers and would be demand constrained, that is, they could hire as many of these workers as they wish at the minimum wage. We set the minimum wage equal to the value of marginal product of high-skill workers and solve for the level of employment. As long as this employment level is less than the labour supply of workers at the minimum wage this means the firm can hire as many workers as it wishes at the minimum wage and is demand constrained:

$$\frac{PA_2 - \overline{w}}{a} < \frac{\psi(\overline{w} - \overline{u}_2)}{t} = \overline{l}_2 \tag{D.7}$$

Using equation (D.7), we solve for the productivity parameter:

$$P^4 = \frac{a\psi(\overline{w} - \overline{u}_2) + t\overline{w}}{tA_2} \tag{D.8}$$

Next, we consider firms who are supply constrained for high-skill workers. That is, they have productivity greater than P^4, but their productivity is not high enough such that they would want to hire any low-skill workers. That is, the marginal productivity of a low-skill worker $VMP_1 = P[A_1 - a(l_2 + l_1)]$, evaluated at minimum wage labour supply of high-skill workers $\bar{l}_2 = \frac{\psi(\overline{w} - \overline{u}_2)}{t}$, is greater than the minimum wage. This will be true as long as productivity is below the following threshold:

$$P^5 = \frac{a\psi(\overline{w} - \overline{u}_2) + t\overline{w}}{tA_1} \tag{D.9}$$

A firm with productivity greater than P^5 will hire all the high-skill workers they can attract at the minimum wage and some low-skill workers. We note here that, if the difference in productivity between high- and low-skill workers were large enough, it may be that the firm will find it more profitable to increase the wage above the minimum wage to attract additional high-skill workers rather than hire low skill workers. If either of these cases were true it would mean that low-skill employment will be even lower in these firms which is in line with the main finding of this section that the share of low-skill workers in a firm will be lowered more by compliance with the minimum wage the further down the firm productivity distribution we go. Given this, we assume for simplicity that the productivity difference between low and high-skill workers is such that firms with productivity greater than P^5 would find it profitable to begin hiring low-skill workers, rather than paying high-skill workers more than the minimum wage.

The next productivity threshold we will adopt is such that firms with productivity above this threshold would employ at least as many in each skill group at the minimum wage as they employed before the minimum wage. Since we saw above that a firm paying the minimum wage will employ all the high-skill workers they can attract at the minimum wage before hiring any low skill workers. For a firm to hire at least as many workers as prior to the minimum wage, they must hire all the minimum wage workers they can attract at the minimum wage ($\bar{l}_2$) plus the number of low-skill workers who were employed before the minimum wage (l_1^1). For it to be profitable for the firm to do this, it must be that the value of marginal product of a low-skilled worker at this level of employment is at least as high as the minimum wage, since otherwise the firm would cut employment.

$$P[A_1 - a(\bar{l}_2 + l_1^1)] = P\left\{ A\theta_1 - a\psi\left[\frac{\overline{w} - \overline{u}\theta_2}{t} + \theta_1\left(PA - \frac{\overline{u}}{t}\right)(Pa\psi + 2)\right] \right\} = \overline{w} \tag{D.10}$$

The solution to this would solve the following cubic equation for the productivity parameter:

$$P\theta_1 \left\{ A - a\psi \left[\frac{\overline{w} - \overline{u}(\theta_2 + 2\theta_1)}{t\theta_1} \right] \right\} + P^3\theta_1 A(a\psi)^2 + P^2\theta_1 a\psi \left(2A - \frac{\overline{u}}{t}a\psi \right) = \overline{w} \qquad \text{(D.11)}$$

In the interests of tractability and demonstrating how the model works, we could adopt a more straightforward productivity threshold where the firm's productivity is high enough such that the value of marginal product of labour of low skill workers, where employment equals all low-skill and high-skill workers willing to supply their labour at the minimum wage, is equal to the minimum wage. That is, the following condition is satisfied:

$$P[A_1 - a(\overline{l}_2 + \overline{l}_1)] = P \left\{ A_1 - a \frac{\psi[2\overline{w} - \overline{u}(\theta_1 + \theta_2)]}{t} \right\} = \overline{w} \qquad \text{(D.12)}$$

We assume that: $tA_1 - a\psi[2\overline{w} - \overline{u}(\theta_1 + \theta_2)] > 0$ and this productivity threshold is:

$$P^6 = \frac{\overline{w}t}{tA_1 - a\psi[2\overline{w} - \overline{u}(\theta_1 + \theta_2)]} \qquad \text{(D.13)}$$

We proceed by showing that there is a threshold for the level of enforcement such that if all workers of either type employed in a firm complain, this firm is sure to be inspected. Also, by choosing the appropriate penalty, the firm can choose a threshold for the productivity parameter such that no worker in a firm below the threshold has the incentive to complain since this will result in the firm shutting down. That is, given that the authorities in different countries may have different preferences over the trade-off between employment and compliance with the minimum wage, we show that, by choosing the appropriate mix of penalties and commitment to inspecting in response to complaints, the authorities will enforce the minimum wage above a given threshold and tolerate non-compliance below it.

The analysis on pages 16-20 establishes the condition outlined in Proposition One, where a threshold for the intensity at which complaints are investigated is established such that non-compliant firms with productivity below a given threshold are certain to be caught if their workers complain. We note that the analysis just described is exactly the same for either low-skill or high-skill workers. That is, we can label the outside option for the skill group in equations (5) to (15) and derive a threshold such that if every worker in any firm employing workers in that skill group

lodges a complaint about minimum wage underpayment, the firm is certain to be investigated:

$$\delta^* = \frac{t(1 - \lambda\sigma)}{\psi\sigma(\overline{w} - \overline{u}_1)} \tag{D.14}$$

The value of δ^* in equation (D.14) is large enough to ensure that the firm will be inspected if all employees of either skill type complain. As in the earlier analysis with one skill group, we proceed by looking at the profit of a firm that is caught in non-compliance. We will seek to establish a level of penalty such that firms with a value for the productivity parameter less than that in P^6 above will close if caught in non-compliance. Workers in either skill group will know this and not complain.

The authorities must set a penalty and a level of enforcement such that workers in firms with productivity less than P are confident that their employers would prefer not to continue in employment if they are caught in non-compliance. The profit of a firm caught in non-compliance is given below, i.e. equation (D.15), and the firm will shut down if caught in non-compliance when this level of profit is negative:

$$\pi(P) = P\left(\sum_{i=1}^{2} A_i \bar{l}_i - \frac{a\bar{l}_i^2}{2}\right) - \overline{w}\bar{l}(P) - \rho[\overline{w} - w(P, \rho)]l_i^1[w(P, \rho)] < 0 \tag{D.15}$$

$$\text{where} \quad \bar{l}_i \leq l_i(\overline{w})$$

For illustrative purposes, we will assume that the authorities choose a threshold value between P^5 and P^6. This means that firms with values of P below the threshold but above P^5 would maximise profit at the minimum wage by hiring all the high-skill workers who would supply their labour at the minimum wage: $\bar{l}_2 = \frac{\psi(\overline{w}-\overline{u}_1)}{t}$ but would hire low-skill workers until their value of marginal product equalled the minimum wage: $P[A_1 - a(\bar{l}_1 + \bar{l}_2)] = P\left\{A_1 - a\left[\bar{l}_1 + \frac{\psi(\overline{w}-\overline{u}_1)}{t}\right]\right\} = \overline{w}$ where employment of low-skill workers equals: $\bar{l}_1 = \frac{A_1}{a} - \frac{\psi(\overline{w}-\overline{u}_1)}{t} - \overline{w}$. The employment of any skill group i prior to being caught in non-compliance in inequality (D.15) is l_i^1.

Proposition Three shows that the profit of a firm caught in non-compliance is increasing in the productivity parameter. This is also true in the case with two ability groups and the argument is essentially the same. We see that the derivative of inequality (D.15) is:

$$\frac{\partial\pi(P)}{\partial P} = \sum_{i=1}^{2} A_i \bar{l}_i - \frac{a\bar{l}_i^2}{2} + X(P) \tag{D.16}$$

As in the one's skill case, we think of a firm with productivity parameter P^x, where this firm has a small increase in productivity. The expression $(\sum_{i=1}^{2} A_i \bar{l}_i - \frac{a\bar{l}_i^2}{2})$ in equation (D.16) denotes the impact of an increase in P on profit evaluated at fixed employment and is positive if the firm has positive output. The second term $X(P)$ represents the sum of the changes in profit that the firm can earn by adjusting employment of each skill type from the optimal value at $P = P^x$ to the optimal values at the new value of P. These optimal values must be positive since the firm can simply not adjust employment of any skill type if this adjustment does not increase profit.

Finally, we need to show that the profit in inequality (D.15) is decreasing in the punishment parameter. We recall the argument from the proof of Proposition Three that for any firm which is below the threshold for the productivity parameter, where a positive profit could be made according to equation (D.5), will put zero probability on being caught in non-compliance in equilibrium since its workers have no incentive to complain. It follows that $\frac{\partial w_i}{\partial \rho} = \frac{\partial l_i}{\partial \rho} = 0$ for each skill group and for firms with values for the productivity parameter where they would close if caught in non-compliance. The derivative of the profit function in inequality (D.15) with respect to the punishment parameter can be written as follows:

$$\frac{\partial \pi(P)}{\partial \rho} = \sum_{i=1}^{2} -\left[\overline{w} - w_i(P, \rho)\right] l_i \left[w_i(P, \rho)\right] < 0 \tag{D.17}$$

It follows that, as in the case with one skill group, for a given minimum wage, the authorities can (i) choose a value for the productivity parameter below which they are willing to tolerate non-compliance, (ii) set the intensity at which inspections are investigated at the level given in equation (D.14) and (iii) choose a value for the punishment variable which ensures that the profit of firms caught in non-compliance at the productivity threshold equals zero. Firms with higher values of the productivity parameter will make positive profit by staying in business if caught in non-compliance and their workers will complain ensuring that they will be caught, so that they will comply with the minimum wage. Firms with values for the productivity parameter below the threshold can safely non-comply as their workers have no incentive to complain, knowing that the firm would sooner shut down than comply with the minimum wage.

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